PB-244 382

WORLDWIDE DISASTER WARNING AND ASSESSMENT WITH EARTH RESOURCES TECHNOLOGY SATELLITES

GEOLOGICAL SURVEY

PREPARED FOR
AGENCY FOR INTERNATIONAL DEVELOPMENT

AUGUST 1975

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PB244382

(IR) NC-47

PROJECT REPORT (IR) NC-47
National Center Investigations
Office of International Geology

WORLDWIDE DISASTER WARNING AND ASSESSMENT WITH EARTH RESOURCES TECHNOLOGY SATELLITES

Prepared for the Office of Science and Technology
and the Office of the Foreign Disaster Relief Coordinator
Agency for International Development
U.S. Department of State

1975

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INFORMATION SERVICE
Springfield, Va. 22151

BIBLIOGRAPHIC DATA SHEET	1. Report No. USGS - GD - 75 - 017	2.	PB 244 382

4. Title and Subtitle Worldwide disaster warning and assessment with earth resources technology satellites.	5. Report Date August 1975 6.
7. Author(s) Charles J. Robinove	8. Performing Organization Rept. No. (IR)NC-47
9. Performing Organization Name and Address U. S. Geological Survey Reston, Virginia 22092	10. Project/Task/Work Unit No. 11. Contract/Grant No.
12. Sponsoring Organization Name and Address Agency for International Development Washington, D. C.	13. Type of Report & Period Covered Final 14.

15. Supplementary Notes

16. Abstracts

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Practical application of satellite images to disaster assessment requires the continued and reliable operation of satellites and data reception stations, rapid distribution of data to interpretive teams and to affected countries, and the rapid analysis and dissemination of maps and other results.

17. Key Words and Document Analysis. 17a. Descriptors

Disasters
Warning
Assessment
Earth Resources Technology Satellite

17b. Identifiers/Open-Ended Terms

PRICES SUBJECT TO CHANGE

COLOR ILLUSTRATIONS REPRODUCED IN BLACK AND WHITE

17c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
Rlease unlimited	UNCLASSIFIED	71
	20. Security Class (This Page) UNCLASSIFIED	22. Price 4.25

FORM NTIS-35 (10-70)

WORLDWIDE DISASTER WARNING AND ASSESSMENT WITH EARTH RESOURCES TECHNOLOGY SATELLITES

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USGS - GD - 75-017

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WORLDWIDE DISASTER WARNING AND ASSESSMENT WITH EARTH RESOURCES TECHNOLOGY SATELLITES

By Charles J. Robinove
U. S. Geological Survey

ABSTRACT

Images of the Earth collected by ERTS-1 and later experimental and operational satellites can be used for the warning and assessment of disasters throughout the world. Floods, fire, glacier movement, and drought are the disasters most amenable to satellite sensing and analysis. Other disasters to which applications are promising but not yet completely feasible are earthquakes, volcanic eruptions, crop failures, and water pollution.

Practical application of satellite images to disaster assessment requires the continued and reliable operation of satellites and data reception stations, rapid distribution of data to interpretive teams and to affected countries, and the rapid analysis and dissemination of maps and other results.

INTRODUCTION AND SUMMARY

The purpose of this report is to define, on the basis of experimental results, the potential use of Earth Resources Technology Satellites (ERTS) for worldwide disaster monitoring, to describe the techniques used for application of ERTS data to disaster monitoring and analysis, and to describe problems and to recommend solutions so as to arrive at an operational disaster monitoring capability. The report was prepared for the Disaster Coordination Office of the Agency for International Development (AID), U. S. Department of State, under PASA PHA(IC)04-74.

The report is not exhaustive, nor does it pretend to be. New and improved results of ERTS experiments are being reported continually, and additional applications are also being identified. It is difficult to predict the many ways that ERTS will be used in the years to come, but this report will attempt to define some requirements which must be met by future systems, if disaster monitoring is to be accomplished. The report begins by defining disasters, then describes briefly the present experimental use of ERTS in disaster monitoring, and concludes by showing the potential for operational use, and the problems that need to be solved in order to make it a reality.

Table 1 summarizes the potential operational use of ERTS data for disaster analysis. It is admittedly optimistic; not all the applications have been realized with the first experimental satellite, but it represents an informed judgment as to "where we can get to from here" if proper attention is paid to disaster analysis in the design and operation of future operational satellite systems. Many types of disasters

Table 1. Summary of disaster and applications of an operational earth resources technology satellite.

[Excellent--experimental results have proven the feasibility and usability. Possible--experiments have not yet been completely successful but are promising. Unproven--Not yet tried or feasibility established. Not applicable.]

Type of disaster and analysis		ERTS Imagery	ERTS data collection system
Floods	Warning	Unproven	*Excellent
	Assessment	Excellent	Not applicable
Earthquakes	Warning	Possible	Possible
	Assessment	Possible	Not applicable
Volcanic eruptions	Warning	Possible	Possible
	Assessment	Possible	Not applicable
Drought	Warning	Possible	*Unproven
	Assessment	Excellent	*Unproven
Fire	Warning	Not applicable	Unproven
	Assessment	Excellent	Not applicable
Crop disasters	Warning	Unproven	*Unproven
	Assessment	Possible	Not applicable
Hailstorms	Warning	Not applicable	Not applicable
	Assesssment	Possible	Not applicable
Glacier movements	Warning	Possible	Possible
	Assessment	Excellent	Not applicable
Water pollution	Warning	Not applicable	Possible
	Assessment	Possible	Possible

*Accuracy improved in conjunction with imagery from the NOAA satellite series and data from weather stations.

with which AID is concerned are obviously not amenable to satellite sensing. They include such things as deep mine collapse, civil strife, border clashes, poisoned food, and similar events. They are not included in this report.

Technical material for this report has been taken from many sources--published literature, communication with ERTS-1 investigators, and contritions by investigators. The conclusions as to the feasibility of individual disaster applications are those of the author and he bears the full responsibility for them.

On January 22, 1975, ERTS-2 was launched by the National Aeronautics and Space Administration (NASA). The satellite and sensors are identical to ERTS-1, but the orbit has been set so that images are obtained midway between the 18-day frequency of ERTS-1. Therefore, images are available, using the two satellite system, on a 9-day frequency for areas within line-of-sight of reception stations.

ERTS-1 and ERTS-2 have been renamed LANDSAT-1 and LANDSAT-2 by NASA. For convenience, however, the previous terminology is used in this report.

Disasters that are most amenable to satellite sensing are floods and grass and forest fires. Initial use of ERTS-type data should be concentrated on these applications because (1) they are widespread and frequent, and (2) the techniques of analysis are developed and readily usable. The use of the ERTS data collection system is also highly feasible for flood warning, particularly if used in conjunction with imagery from the NOAA satellite series and data from weather stations.

Secondarily, use of ERTS data for glacier movement and drought seems feasible but are less well developed than for flood and fire. Glacier movement can readily be determined from the ERTS images, but damage from glaciers, either from surges or from floods, is not frequent and is limited geographically to such areas as parts of Alaska, Iceland, USSR, etc.

Detection of impending drought over wide areas seems to be feasible on the basis of the characteristics of ERTS data, but it has not yet been done experimentally and will require a longer period of ERTS-type data for a base than is now available.

Figure 1 qualitatively shows the value of ERTS data for disaster relief. Note that while there is an almost immediate value in many cases, there is also future value for planning of anticipated disaster situations based on the historical record. In addition, an excellent data base is provided for future studies, predictive modeling, and planning.

An operational system for the collection and delivery of useful ERTS data must be capable of imaging any disaster area and providing data on a timely basis to interpretive teams. Even more important, however, is the need to have interpretive teams available on short notice to react to disasters and to provide the data interpretations and maps quickly to users both in AID and in the affected countries.

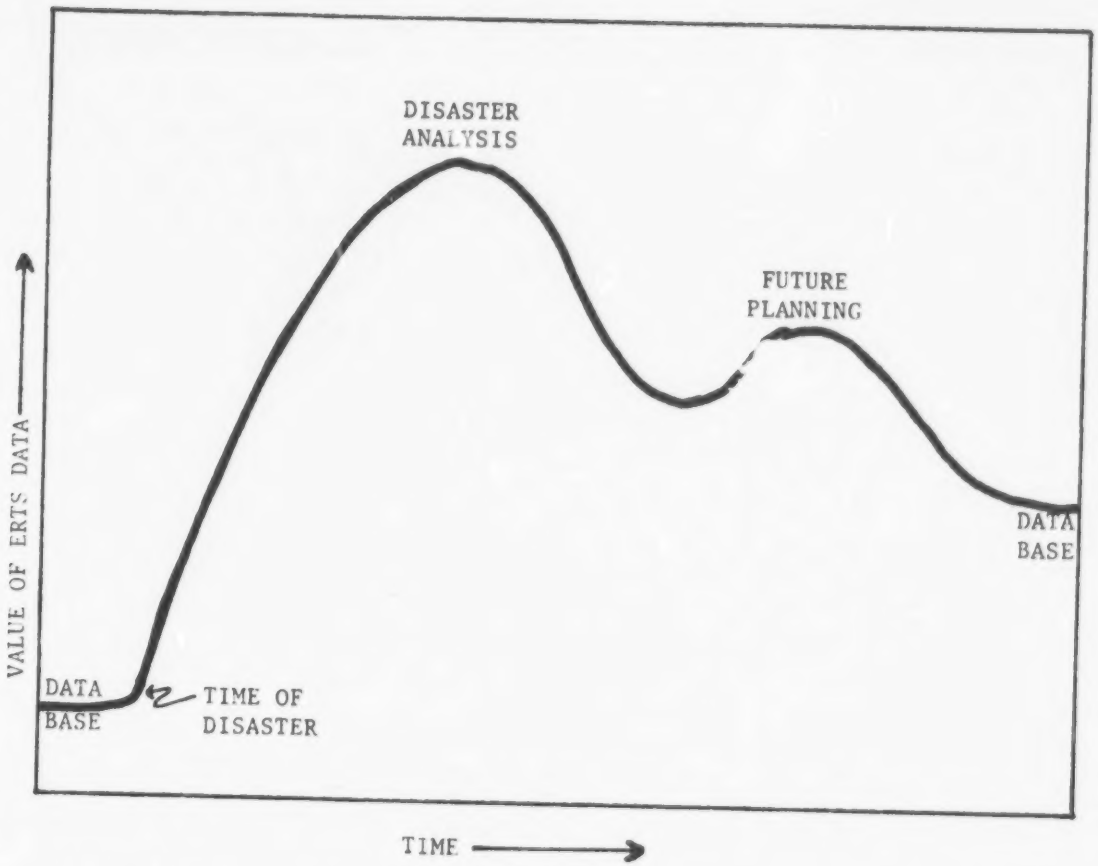


Figure 1. -- Value of ERTS data versus time for disaster applications. An initial base of ERTS data is used for pre-disaster assessment. Images at or shortly after a disaster increase the value of the data base, because changes can be detected and mapped for analysis of the disaster and its effects.

Later data use for future planning, both for mitigation of disasters and avoidance planning, provides an additional value. At that time the data base value is increased because of the previous analyses.

DISASTER DEFINITIONS, MAGNITUDES, AND FREQUENCY

For the purposes of this report, disasters are divided into two classes--sudden and creeping. Sudden disasters are those events that occur with little or no warning. Prime examples are earthquakes and volcanic eruptions. In the case of some disasters, such as floods, there may be a high probability that a catastrophic flood may occur within a given time period, but its exact timing and magnitude cannot readily be predicted.

Creeping disasters are those events whose eventual or total impact may be catastrophic, but which proceed slowly toward their culmination and initially exhibit only subtle hints of their eventual impact. A prime example is drought, which may affect the agricultural production and food supplies of a large region but may not be identified as such for some time after its onset.

The magnitude of a disaster can be measured in several ways--loss of life, loss of property, and loss of economic productivity.

In the 1970 disaster report of AID[1/], 40 disasters were reported which required help. Of these, 27 disasters would have been amenable in part, to satellite sensing as a means of analyzing the magnitude and effects of the disaster. The disaster list (from the table of contents of the 1970 report) is analyzed in table 2.

ERTS EXPERIMENTAL RESULTS

ERTS-1 was launched on July 23, 1972, and has provided over 100 thousand multispectral images of most of the land areas of the world. Thus, we have had nearly 3 years of satellite data to study in relation to natural resources, environmental management, and disaster monitoring. Only a few of the formal experiments that were proposed for analysis of ERTS data prior to launch of the satellite concerned themselves with the monitoring of disasters. However, because of the occurrence of a number of disasters during the time when the data were acquired, opportunities have been taken by various groups to test the utility of ERTS data. In this section both the results of formal experiments and results of "experiments of opportunity" will be described as evidence for the conclusion that disaster monitoring by ERTS or by future operational systems can aid significantly in the analysis and monitoring of disasters.

The applications of ERTS data to disasters presented in the following sections are the results of both formal and informal ERTS-1 experiments. The formal experiments are those that were selected and funded by NASA from about 700 proposals for specific studies in many resource and environmental disciplines. Informal experiments are those conducted by government, university, and industrial scientists as ERTS data became available and as opportunities for study were recognized.

1/ Agency for International Development [1971], Foreign disaster emergency relief: tenth rept., W588, fiscal year 1970, 327 p.

Table 2. Analysis of amenability to satellite sensing of disasters reported in AID 1970 annual report.

Disaster amenable in part to satellite sensing	Disaster not amenable to satellite sensing
Afghanistan--Drought	Bolivia--Polio
Algeria--Floods	Chad--Food Shortage
Botswana--Drought	Cyprus--Windstorm
Ceylon--Flood	El Salvador, Honduras--Undeclared war
Colombia--Floods	El Salvador, Guatemala, Honduras, Nicaragua--Equine encephalitis
Colombia--Floods	Indonesia--Famine
Costa Rica--Floods	Korea--Cholera
Costa Rica--Floods	Malagasy Republic--Cyclone
Ecuador--Floods	Mali, Niger, Nigeria, Upper Volta--Yellow Fever
El Salvador, Guatemala, Honduras--Hurricane Francelia	Niger--Meningitis
Ethiopia--Drought	Pakistan--Urban Fire
Jordan--Drought	Taiwan--Typhoons
Korea--Drought	Togo--Displaced Persons
Laos--Flood	
Mali--Drought	
Morocco--Floods	
Panama-- Floods	
Peru--Oct. 1969--Earthquake	
Peru--Floods	
Peru, May 1970--Earthquake	
Romania--Floods	
Somalia--Drought	
Surinam--Floods	
Tunisa-- Floods	
Turkey--Earthquake	
Upper Volta--Drought	
Yugoslavia--Earthquake	

Each type of disaster is summarized in a narrative and outline form and is followed by abstracts of formal investigators' reports that are pertinent. The abstracts are from only two of several symposia on ERTS results that have been held by NASA and other organizations. The abstracts should be consulted for complete papers and additional results of interest.

NASA, 1973, Proceedings of symposium on significant results obtained from the Earth Resources Technology Satellite-1; v. 1, Technical Presentations, NASA SP-327, 1730 p.; v. II, Summary of results, NASA X-650-73-127, 198 p.; v. III, Discipline Summary Reports, NASA X-650-73-155, 118 p., March 1973.

NASA, 1973, Third Earth Resources Technology Satellite-1 symposium, abstracts, v. 1, Technical Presentations, NASA SP-351, 1992 p., December 1973.

Abstracts from publications other than the two above are given with complete citations.

Introduction and data base definition

This section briefly describes the characteristics of ERTS-1 data and the means by which data are delivered to interpreters. The Earth Resources Technology Satellite is a small unmanned satellite that is in a near-polar, sun-synchronous orbit. It contains two imaging systems and a Data Collection System (DCS). The first imaging system consists of three Return Beam Vidicon (RBV) (television) cameras imaging in the green, red, and solar-infrared parts of the spectrum. The second imaging system is a Multispectral Scanner (MSS) which images in the green, red, and two parts of the solar-infrared range of the electromagnetic spectrum. Both systems image the same area on the ground in all bands. A malfunction in the electrical system of the satellite has prevented the use of the Return Beam Vidicons since a few weeks after the launch but has not affected the performance of the Multispectral Scanner. The Data Collection System has the capability to relay data measured by ground sensors to the satellite and then to central processing stations and to users. It will be discussed later in more detail because of its high applicability to disaster monitoring.

Because of the sun-synchronous orbit of the satellite, it has the capability to image any area of the world, with the exception of approximately 9° around both the North and South Poles. The Multispectral Scanner images a strip 185 km in width on each revolution. Ground commands are given to the satellite to turn the scanner on and off, depending upon areas of interest for imaging, and upon cloud cover predictions. The images, when processed on the ground, are converted into frames covering 185 km on a side. The satellite passes over the same spot on Earth every 18 days. Adjacent swaths overlap by approximately 10 percent at the Equator and increasingly higher percentages as the poles are reached.

At the higher latitudes, therefore, it is possible to obtain images of the same point 2, 3, or even 4 days in succession, but this is not possible nearer the Equator. The images from the MSS are telemetered to reception stations operated by NASA at the Goddard Space Flight Center, Greenbelt, Maryland; Fairbanks, Alaska; and Goldstone, California. In addition, ground receiving stations are operating in Brazil and in Canada, and other stations are being contemplated by additional countries. The data, which is telemetered in digital form, are recorded on magnetic tape and processed into photographic form at the Goddard Space Flight Center. The original photographic reproduction is on 70 mm film with images at a scale of 1:3,369,000. These are enlarged to the second standard format which are approximately 18 cm- (approximately 7 in-) wide images at a scale of 1:1,000,000 (1 mm represents 1 km). Composites of the multispectral images can also be made in false color to aid interpretation. Figure 2 is an example of one of the typical ERTS images showing the four multispectral bands and a false-color composite made from them. The images may be enlarged to scales as large as 1:100,000 (1 cm represents 1 km) with standard enlarging equipment, but special equipment and procedures are needed for larger scales than this. Scales larger than 1:100,000 are not generally used with photographic reproduction.

The images are stored on high-density digital tape which can be converted to computer-compatible tapes, so that each picture element in the scene is a discrete element and can be processed, enhanced, or subdued by using a digital computer. This has permitted processing of the data to scales as large as 1:24,000.

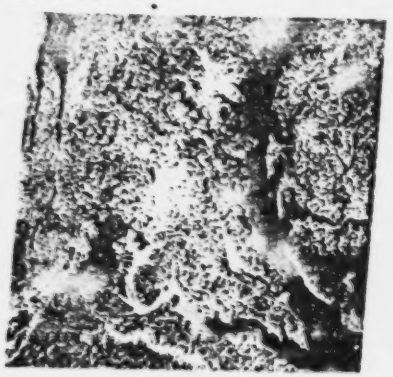
Of particular importance is the uniform character of the data on a worldwide basis, so that comparisons can be made from area to area and within a given area from one time to another. This time comparison of data or "temporal compositing," in the jargon of the technology, is of extreme importance in the monitoring of changing features and is discussed in some detail in the section on the Mississippi River and Indus River floods of 1973.

Thus, the characteristics of the ERTS data that make it suitable for some kinds of disaster monitoring are: the ability to obtain images anywhere in the world at scheduled intervals, the uniform character of the data; the ability to reproduce the data readily for interpreters; the large areas covered; the multispectral nature of the data which aids in recognition of environmental phenomena; the ability to process the data by digital computer for feature recognition and mapping; and the ability to automatically produce temporal composites for change detection.

In addition to the ERTS imaging system, the Data Collection System (DCS) is of value in disaster monitoring. Data from ground-based sensors, such as stream gages and seismic event counters, can be relayed through the ERTS DCS to central reception stations and thence to users. This capability has been used to monitor the filling and emptying of large reservoirs in Arizona to prevent floods from large upstream storms, and for monitoring volcanoes for precursor signs of eruption. Use of

ERTS-1 MULTISPECTRAL SCANNER

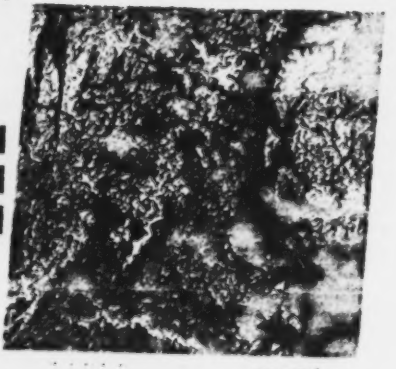
BAND 4



BAND 5

"FALSE-COLOR" COMPOSITE

Derived by combined processing of three bands (4, 5 and 6 or 7) through appropriate filters onto color film.

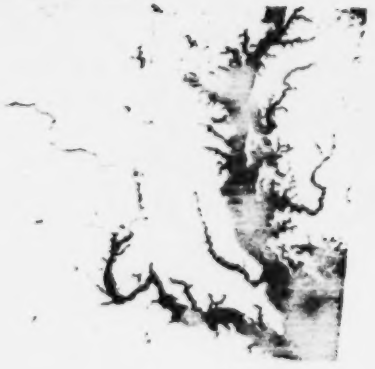


BLUE FILTER

GREEN FILTER

RED FILTER

BAND 6



BAND 7

NATION'S CAPITAL AREA, 11 October 1972. Vegetation in vigorous growth appears red, clear water black, and water that carries silt is a light blue. Scale of image is 1:1,000,000.

Figure 2. -- ERTS multispectral images and color composites are the basis of disaster interpretation. Scale [illegible]. Image [illegible].

Reproduced from best available copy.

the DCS system is restricted to line-of-sight applications, because DCS data is not tape recorded in the satellite. Future operational uses on a worldwide basis will require further development and experimentation.

Additional satellite data, such as that from meteorological satellites, which have a higher frequency of coverage, are probably applicable to disaster monitoring. Specific experiments to determine the precise methods of use have not been conducted.

Global data base available for change detection

The existence of an image data base that covers the land areas of the world in a uniform manner makes it possible to detect changes that take place in natural or manmade features by the simple means of temporal composites--compositing ERTS images from two or more dates--which allow the ready recognition of features that have changed over time, and thus may well facilitate the recognition of early signs of creeping disasters. This may be particularly important, for example, in areas of drought and increasing desertification.

For example, if there is no cloud cover over a given area, as many as 20 images of the same area may be obtained per year. Cloud cover may reduce this slightly in arid regions, and severely in humid regions.

Floods

Description

Floods are the most widespread, frequent, and damaging disasters that occur in the world. Fortunately, they are the most amenable to satellite sensing of any of the disasters considered in this report. The contribution of satellite sensing to the knowledge of floods can be summarized as follows:

(1) It allows the delineation of areas inundated by an individual flood.

(2) When combined with previously made maps of land use, it allows rapid calculation of the areas of each type of land that are subject to flooding and the consequent prediction of the economic consequences, particularly in agriculture.

(3) Together with topographic maps and stream-gage data, it aids in the assessment of the areas inundated by floods as individual events and in the documentation of statistical frequencies of classes of floods.

(4) It provides significantly useful basic data for planning for flood control and protection measures.

At the present time, however, satellite sensing cannot generally: (1) identify and map damage to individual structures such as factories, houses, bridges, and roads; or (2) provide, by itself, knowledge of the discharge of a particular flood.

Methods of flood mapping from ERTS imagery were first demonstrated by the Iowa Geological Survey and the U.S. Geological Survey for floods of the Nishnabotna River in Iowa in 1972. This was followed by mapping,

by the U.S. Geological Survey, of the Mississippi River floods of 1973, which was done in great detail (fig. 3), and by rapid analysis of the area flooded by the Indus River in Pakistan in 1973 (fig. 4). In addition, data from ground sensors relayed by the ERTS Data Collection System were used to control reservoir release programs to minimize flooding along the Salt River in Arizona in 1973. The significant conclusion from these studies is that the area inundated by a particular flood can readily be mapped by the ERTS data. In addition, it is not necessary that the images be taken at the crest of the flood, because the near-infrared spectral reflectance of wet ground after the flood has receded can indicate the area that was previously flooded. This, to a large extent, means that the 18-day repeat time of the satellite over a given area is not a significant disadvantage in flood mapping. Coastal flooding caused by hurricanes and typhoons can be mapped in a similar manner. Erosion and deposition along the affected coasts can be mapped and continually monitored after the storms.

At the present time, the means of mapping floods with ERTS imagery is known, the techniques are readily used, and this application can be considered ready for systematic use when required.

Summary

Definition of the problem: Identify and map the inundated area to aid in relief and reclamation and in future planning for flood plain protection.

Basis for the use of ERTS data:

1. Synoptic view allows uniform mapping of large areas.
2. Multispectral data allows differentiation of flooded and nonflooded land.
3. Repetitive images allow time comparison and compositing of images to provide "instant maps" of floods.

Experimental results:

1. Mississippi flood studies developed techniques for temporal compositing of images and mapping of inundated areas in a highly successful manner. Techniques are published and are applicable anywhere in the world.
2. Iowa flood studies showed good correlation between ERTS and aircraft flood mapping, and also that flooded areas can be mapped some days after flood recession because of the decrease in reflectance of the flooded ground.
3. Use of Data Collection System on ERTS-1 aided in prevention of floods in Salt River, Arizona, by quick relay of gaging station data.

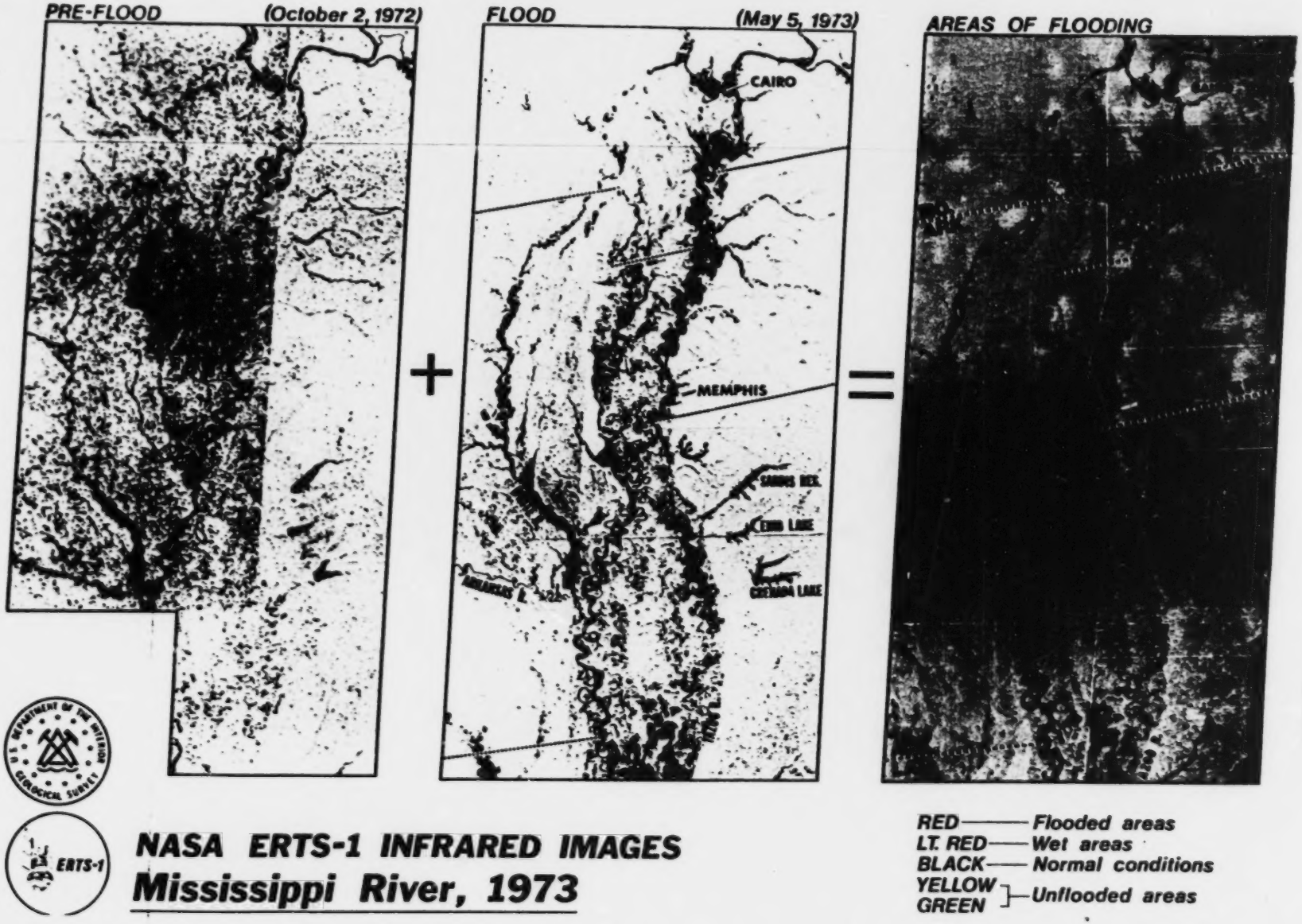


Figure 3. -- Flooded area along the Mississippi River in 1973 is shown by special processing of ERTS images to enhance changes. Scale 1:3,350,000.

Figure 4. -- Flooded area along the Indus (left) and Helm (right) Rivers in Pakistan is shown by a temporal composite of ERTS images. Band 7 images taken after the flood and during the flood (3 September 1973) were placed in registry in two colors. The resulting color print shows the flooded area in orange in contrast to the green and yellow of the nonflooded areas.

Scale 1:1,000,000. Images 1137-05200 and 1407-05184.

References: Deutsch, M., Ruggles, F. H., Guss, P., and Yost, E., 1973, Mapping of the 1973 Mississippi River floods from the Earth Resources Technology Satellite (ERTS): in Remote Sensing and Water Management. Proc. No. 17, American Water Resources Association, Urbana, Illinois, p. 39-55.

Evaluation of status of application:

Application proven and ready for use
Techniques published
Equipment available
Little training required for use

Potential use of operational system:

1. Mapping of flooded areas anywhere in the world.

2. Rapid measurement of area of damaged land.

3. Check on accuracy of ground estimates of flooded area.

4. Aid in planning reclamation measures and logistics of disaster relief.

5. Aid in planning future flood prevention measures.

Abstracts

Assessment of Flood Damage in Arizona by Means of ERTS-1 Imagery

by

Roger B. Morrison and Maurice E. Cooley
U.S. Geological Survey

Abstract

ERTS-1 MSS images clearly show two important effects of a large flood in southeastern Arizona - the extent of inundation and the areas affected by severe sediment deposition and erosion - although the images were made a week and half after the flood. On October 20 and 21, 1972, the upper Gila River had its third-largest flood on record. Peak flows attained about 42,000 and 82,000 cubic feet a second at Duncan and Safford, Arizona, respectively. Two lives were lost, hundreds of people made homeless, and more than 10,000 acres of cropland inundated.

The first ERTS-1 images after the flood were made on November 1 and 2. The inundated area is best displayed on the infrared bands, particularly on band 7, where it appears as a belt along the river that is distinctly darker than adjoining parts of the flood plain. This dark belt does not appear on ERTS images that predate the flood. Presumably the low infrared reflectance of this belt is caused by still-moist soil and by flood-stressed vegetation. Inundation limits mapped from ERTS imagery agree well with those obtained by aerial photography during the flood and by ground surveys. Areas of severe sand and gravel deposition show best on band 5. By comparing before and after flood images in this band, a quick assessment can be made of the severely flood-ravaged land.

Application of ERTS-1 Imagery to Flood Inundation Mapping

by

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Remote Sensing Laboratory

Albert Rango
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Abstract

In September 1972, heavy rains initiated major flooding in southwestern Iowa, concentrated in the East and West Nishnabotna basins. The flood crest moved downstream between September 11-15. A cooperative program to evaluate the possibility of mapping flood inundation using remote sensing techniques was initiated jointly by the Iowa Geological Survey, Remote Sensing Laboratory (IGSRSL), and the U.S. Geological Survey, Water Resources Division. Ground data and a variety of low-altitude multispectral imagery was acquired for the East Nishnabotna River on September 14-15. This successful effort concluded that a near-visible infrared sensor could map inundated areas in late summer for at least three days after flood recession. ERTS-1 imagery of the area was obtained on September 18-19. Analysis of MSS imagery by IGSRSL, USGS, and NASA reinforced the conclusions of the low-altitude study while increasing the time period critical for imagery acquisition to at least seven days following flood recession. The capability of satellite imagery to map late summer flooding at a scale of 1:250,000 is exhibited by the agreement of interpreted flood boundaries obtained from ERTS-1 imagery to boundaries mapped by low-altitude imagery and ground methods. The synoptic coverage of ERTS-1 allowed extension of the flood mapping to the West Nishnabotna River. Satellite imagery allows rapid appraisal of the areal extent of flood inundation for entire river systems. This satellite flood mapping should prove valuable to federal and state agencies involved in regional floodplain management and planning.

ERTS-1 Flood Hazard Studies in the Mississippi River Basin

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Abstract

The Spring 1973 Mississippi River flood was investigated using remotely sensed data from ERTS-1. Both manual and automatic analyses of the data indicate that ERTS-1 is extremely useful as a regional tool for flood and floodplain management. Automatic digital analysis using the GEMS system was employed to obtain quantitative estimates of area flooded in small test sites 1225 km^2 in area in St. Charles County, Missouri, and the delta region of northwest Mississippi. In the St. Charles County site 265 km^2 (21% of the total area) were calculated to be flooded whereas, in the northwest Mississippi site, 480 km^2 (39%) were inundated with an additional amount of high forest submerged beneath the canopy. In the entire State of Arkansas, manual photointerpretation indicated that 7300 km^2 were inundated with only 630 km^2 flooded along the Mississippi River mainstem. The maximum error of such flood area measurements is conservatively estimated to be less than five percent. Change detection analysis indicates that the flood had major impacts on soil moisture, land pattern stability, and vegetation stress.

Flood hazard identification (i.e., the delineation of flood-susceptible areas) was conducted using photointerpretation techniques in three study areas along the Mississippi River using pre-flood ERTS-1 imagery down to 1:100,000 scale. The flood-prone areas delineated on these images correspond to areas that would be inundated by significant flooding (approximately the 100-year flood). In addition, in northwest Mississippi, the feasibility of objective detection of floodplain features related to flood susceptibility was confirmed using the GEMS system. Flood prone area boundaries obtained from ERTS-1 were generally in agreement with flood hazard maps produced by the U.S. Army Corps of Engineers and the U.S. Geological Survey although the latter are somewhat more detailed because of their larger scale. Initial results indicate that ERTS-1 digital mapping of the flood-prone areas using the Purdue University LARS system can be performed at least at 1:62,500 which is comparable to conventional flood hazard map scales. Direct comparison of the ERTS-1 digital products to conventional flood hazard maps must wait until corrections for image skew can be incorporated into the LARS output format.

Optical Data Processing and Projected Applications of the ERTS-1 Imagery Covering the 1973 Mississippi River Valley Floods

by

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U.S. Geological Survey

Fred Ruggles
Water Resources Division
U.S. Geological Survey

Abstract

Flooding along the Mississippi River and some of its tributaries was detected by the multispectral scanner (MSS) on the Earth Resources Technology Satellite (ERTS-1) on at least three orbits during the spring of 1973. The ERTS data provided the first opportunity for mapping the regional extent of flooding at the time of the imagery. Special optical data processing techniques were used to produce a variety of multispectral color composites enhancing floodplain details. One of these, a 2-color composite of near infrared bands 6 and 7, was enlarged and registered to 1:250,000-scale topographic maps and used as the basis for preparation of flood image maps. Two specially filtered 3-color composites of MSS bands 5, 6, and 7 and 4, 5, and 7 were prepared to aid in the interpretation of the data. The extent of the flooding was vividly depicted on a single image by 2-color temporal pre-flood band 7 images. On May 24, when the floodwaters at St. Louis receded to bankfull stage, imagery was again obtained by ERTS. Analysis of temporal data composites of the pre-flood and post-flood band 7 images indicate that changes in surface reflectance characteristics caused by the flooding can be delineated, thus making it possible to map the overall area flooded without the necessity of a real-time system to track and image the peak flood waves. Regional planning and disaster relief agencies such as the Corps of Engineers, Office of Emergency Preparedness, Soil Conservation Service, interstate river basin commissions and state agencies, as well as private lending and insurance institutions, have indicated strong potential applications for ERTS image-maps of flood-prone areas.

Hydrologic Application of ERTS-1 Data System in Central Arizona

by

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Abstract

The Earth Resources Technology Satellite (ERTS-1) Data Collection System (DCS) was used to relay hydrologic data (streamflow rates, precipitation amounts, soil and air temperature, and snow-moisture content) from remote sites in Central Arizona to those responsible for reservoir management. Three U.S. Geological Survey streamflow gaging stations, 1 meteorological station and 2 snow-moisture content installations were equipped with ERTS-1 Data Collection Platforms (DCP's).

By mid-March 1973, the high moisture levels on the Salt and Verde River watersheds, reduced reserve reservoir storage capacity, and a large potential for flooding in the Salt River Valley presented a critical water management situation. Beginning on March 15, 1973, the ERTS-DCS was utilized to furnish near-real time information on snow-moisture content and streamflow rates to the Salt River Project for use in the management and operation of reservoirs on the Salt and Verde Rivers. The Salt River Project, aided by near-real time hydrologic data furnished by both microwave and ERTS-telemetry, was successful in predicting the volume of runoff into the reservoirs. Serious flooding in the downstream Phoenix metropolitan area was prevented by prudent water management.

Earthquakes

Description

An extensive research effort has gone into the methods for predicting earthquakes and into the engineering of structures to make them resistant to earthquakes. Only during the past year has research in earthquake prediction progressed so far that an earthquake has actually been predicted. Satellite remote sensing is of potential value in the delineation of earthquake-prone areas and in assessing the regional effect of earthquakes. As in the case of flood assessment, satellite images do not have sufficient resolution for the delineation of damaged buildings, structures, and transportation networks, but satellite coverage on a regional basis can be supplemented by high- or low-altitude aerial photography for such detailed assessments.

ERTS data were first used during the earthquake at Managua, Nicaragua, on December 23, 1972. Twelve hours after the earthquake shock, images of the Managua area were taken by the ERTS Multispectral Scanner. The City of Managua, however, was cloud covered at the time. An analysis of the regional lineament pattern, which may indicate faults and fractures, was made on the ERTS images (fig. 5). Some parts of the regional system within the city of Managua were mapped by ground surveys. Faults are areas that should be avoided in siting buildings and transportation networks. The lineament pattern analysis is of assistance in post-earthquake planning for reclamation and resiting. The ERTS data, however, are not useful in detailed disaster assessment. Digital data enchancement of damaged areas at large scale may be usable, but has not yet been tried in earthquake areas. Landslides accompanying earthquakes can be recognized and mapped on ERTS images if they are of of sufficient size (larger than a football or soccer field).

The ERTS Data Collection System also plays an important role in earthquake warning. Seismic event counters can relay data through the DCS to warn of impending earthquakes. In addition, other seismic data and data from other sensors such as stream gages may also be transmitted. Research is continuing on this subject.

Summary

Definition of the problem: Assessment of the regional setting of earthquakes to aid in resiting of facilities and future regional planning.

Basis for the use of ERTS data: The synoptic regional view provides a basis for regional lineament mapping that aids in delineation of earthquake-prone areas.

Experimental results: The Managua, Nicaragua, earthquake of 1972 was covered by ERTS 1 day after the earthquake. An analysis of the regional lineament pattern was made as an aid to future planning and facility siting. No use of ERTS data was made in direct disaster relief efforts because the details of damage to structures, etc., cannot be seen.

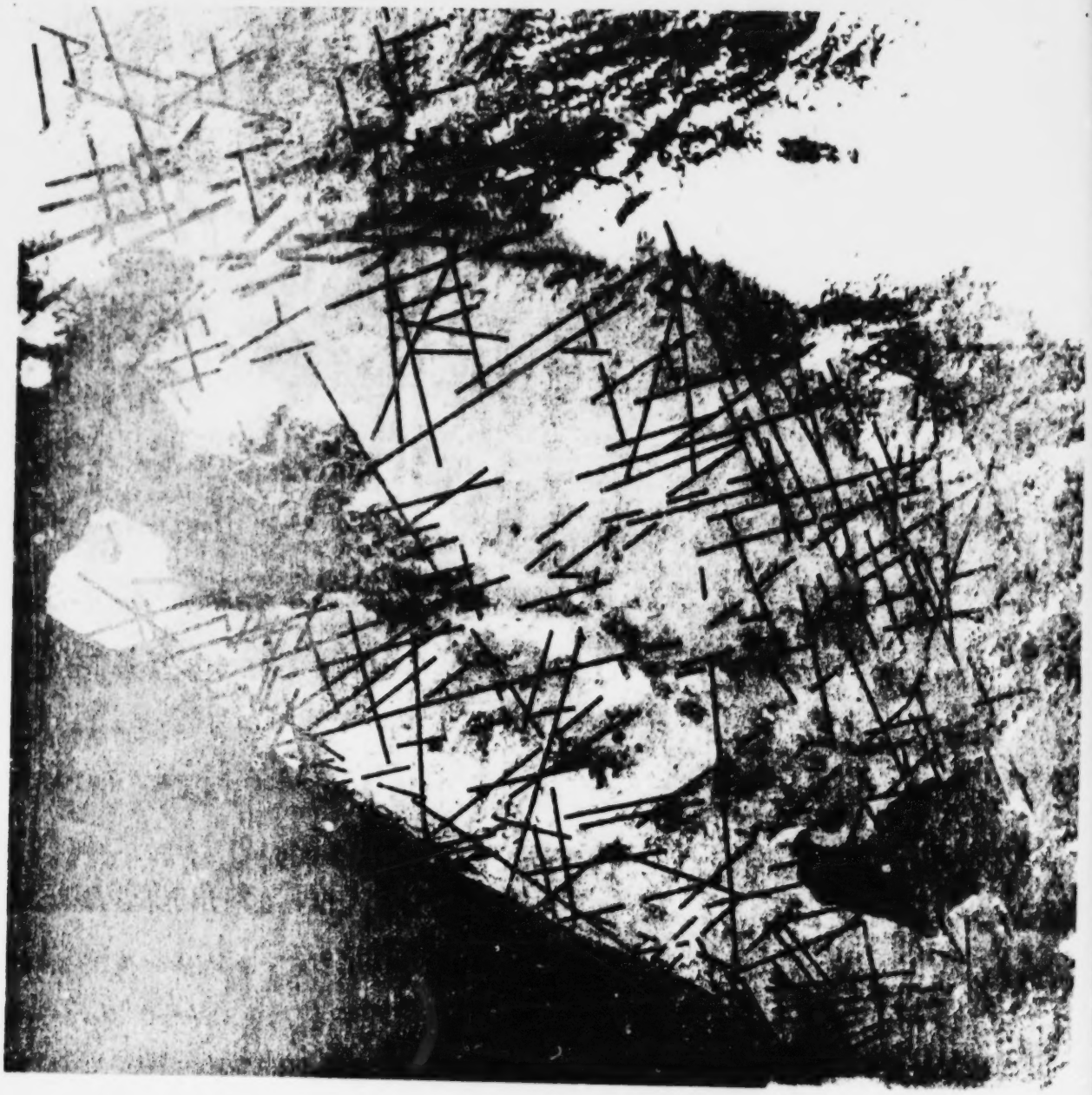

Figure 5.--Lineament patterns in the earthquake-prone area of Managua, Nicaragua, are mapped on an ERTS image. Managua is in the southeast corner of the image, which was taken on December 4, 1972, twelve hours after a magnitude 5.6 earthquake had destroyed much of Managua and the surrounding area. The ERTS image and regional lineament map allows an assessment of the regional geology that can be related to the earthquake and used for future planning and siting of development.

Scale 1:1,000,000. Image 1154-15385.

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References: See abstracts following.

Evaluation of status of application: ERTS data best used in regional planning for avoidance of earthquake-prone areas.

Potential use of operational system: Up-dated analysis of earthquake-prone areas.

Abstracts

ERTS-1, Earthquakes, and Tectonic Evolution in Alaska

by

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University of Alaska

Abstract

In comparing seismicity patterns in Alaska with ERTS-1 imagery, one is struck by the frequency with which earthquake epicenters fall on, or near, lineaments visible on the imagery. Often these lineaments prove to be tectonic faults which have been mapped in the field. But equally as often, existing geologic and tectonic maps show no evidence of these features. The remoteness and inaccessibility of most of Alaska is responsible, in large part, for the inadequacy of the mapping. ERTS-1 imagery is filling a vital need in providing much of the missing information, and is pointing out many areas of potential earthquake hazard.

Earthquakes in central and south-central Alaska result when the northeastern corner of the north Pacific lithospheric plate (roughly enclosed by the great bend in the Alaska Range near Mt. McKinley) underthrusts the continent. North of Mt. McKinley, the seismicity is continental in nature and of shallow origin, with earthquakes occurring on lineaments, and frequently at intersections of lineaments. South of Mt. McKinley, the seismicity is generally deeper and is associated with the subduction of the Pacific plate. The shallower events, however, still tend to align themselves with lineaments visible on the imagery. These two areas are separated by the Denali fault.

Offset along the Denali fault has long been a matter of conjecture. Cooperative studies involving radiometric dating, geologic mapping, and use of ERTS-1 imagery have now provided the first firm evidence of the magnitude of this offset (Turner, Smith, and Forbes, 1974). In south-central Alaska, a prominent lineament which is truncated by the Denali fault separates K-Ar dated metamorphics of mid- and latest-Cretaceous ages. In Yukon Territory near Kluane Lake, another strong lineament on the opposite (north) side of the Denali fault separates metamorphics of mid-Cretaceous age from igneous and metamorphic rocks yielding 57 m.y. dates. This lineament is also truncated by the Denali fault. Both lineaments intersect the Denali at the same angle. Turner et al. believe that these lineaments were once contiguous, indicating that the total amount of right-lateral offset along the Denali fault since Cretaceous is about 400 km.

ERTS-1 Image Contributes to Understanding of Geologic Structures Related to Managua Earthquake, 1972

by

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Abstract

ERTS-1 imaged the western portion of Nicaragua on December 24, 1972, one day after the central part of the city of Managua was devastated by a major earthquake which measured 5.6 on the Richter scale. ERTS-1 images reveal four sets of lineaments (which may reflect fault systems) along any one of which movement could have taken place. One set, trending N 50° W, includes a line of active volcanoes that parallels the coast and constitutes the southwestern edge of the Nicaraguan Depression, a regional graben which cuts obliquely across the Central American isthmus. This trend is offset approximately 10km in a right lateral geometric sense just west of the city of Managua. A parallel lineament, noth of Lake Managua, marks the northeast edge of the graben. A second set, trending due N-S to N 25° W, extends northward to northwestward from the mouth of the Rio Grande (Viejo) north of Lake Managua and can be projected southward across the lake to Managua. It is this set along which geometric offset of the volcanic lineament appears to have taken place. It is paralleled by a belt of young pit craters at the west edge of the city. A third set of linears trends approximately N 50°-60° E across the Nicaraguan trench. The fourth set, which is less conspicuous, is represented by only three identified members within Nicaragua. Two others, which are subparallel, are visible on the image in the area of Honduras, to the northwest. This set is notable for the fact that it extends from the coast entirely across the Nicaraguan Depression. Its trend is N 25°-45° E. Aerial photographs and field studies in the city of Managua by other U.S. Geological Survey personnel (Brown, Ward, and Plafker, in press) indicate that this fourth set is represented by four currently active, left-lateral, strike-slip faults and a narrow belt of aftershock epicenters. Instrumental data indicate that the aftershock earthquake foci are of shallow depth (<10.0 kilometers).

Volcanic eruptions

Description

Volcanic eruptions affect many areas of the world with great loss of life and property. Methods of predicting volcanic eruptions include precise measurement of the tilt of volcanoes prior to eruption, measurement of the geochemistry of gases and increased heat flow from volcanoes, and the measurement of microseismic activity which may precede an eruption. The ERTS Data Collection System can relay data from tilt meters and seismic event counters to central reception stations to warn of impending eruptions. Indeed, this was done for the first time, retrospectively, on Volcán Fuego in Guatemala in 1973. Figure 6 illustrates the relationship. It has been proven that such data are reliable precursors of eruptions of some active volcanoes in Hawaii, Japan, and Kamchatka, but they may not be applicable to all volcanoes.

Assessment of damage from volcanic eruptions can be made in a preliminary fashion from ERTS images, particularly mapping the areas of lava flows and the areas covered by falls of windborne ash and other volcanic ejecta (tephra). The tephra may have lasting effects on growth of vegetation both near the site of an eruption and at some distance from it. Even very light ash falls, which may not be visible immediately after an eruption, may betray their presence by a lack of vigor in vegetation shortly after the eruption.

Summary

Definition of the problem: Predicition of volcanic eruption and monitoring of the impact of active eruptions.

Basis for the use of ERTS data: Images used for mapping of new lava flows and tephra falls in volcanic areas. Data Collection System relays seismic data prior to eruption as a warning of impending eruption.

Experimental results: Measurement of seismic events and ground tilt can indicate impending eruptions. A low cost reliable network of recording and satellite transmitting stations could be set up on volcanoes. Several volcanic eruptions during the experiment were preceded by abnormally large swarms of earthquakes several days before eruptions.
Not yet proven that all volcanoes give the same type of seismic warnings. Research is continuing on this subject. Recent lava flows and areas blanketed by tephra (volcanic ash) have been mapped.

References: See abstracts following.

Evaluation of status of application:

Equipment and techniques completely developed.

System could be implemented now on a worldwide basis utilizing satellite relay through ERTS or through communications satellites.

Need for rapid dissemination of imagery for disaster assessment analysis.

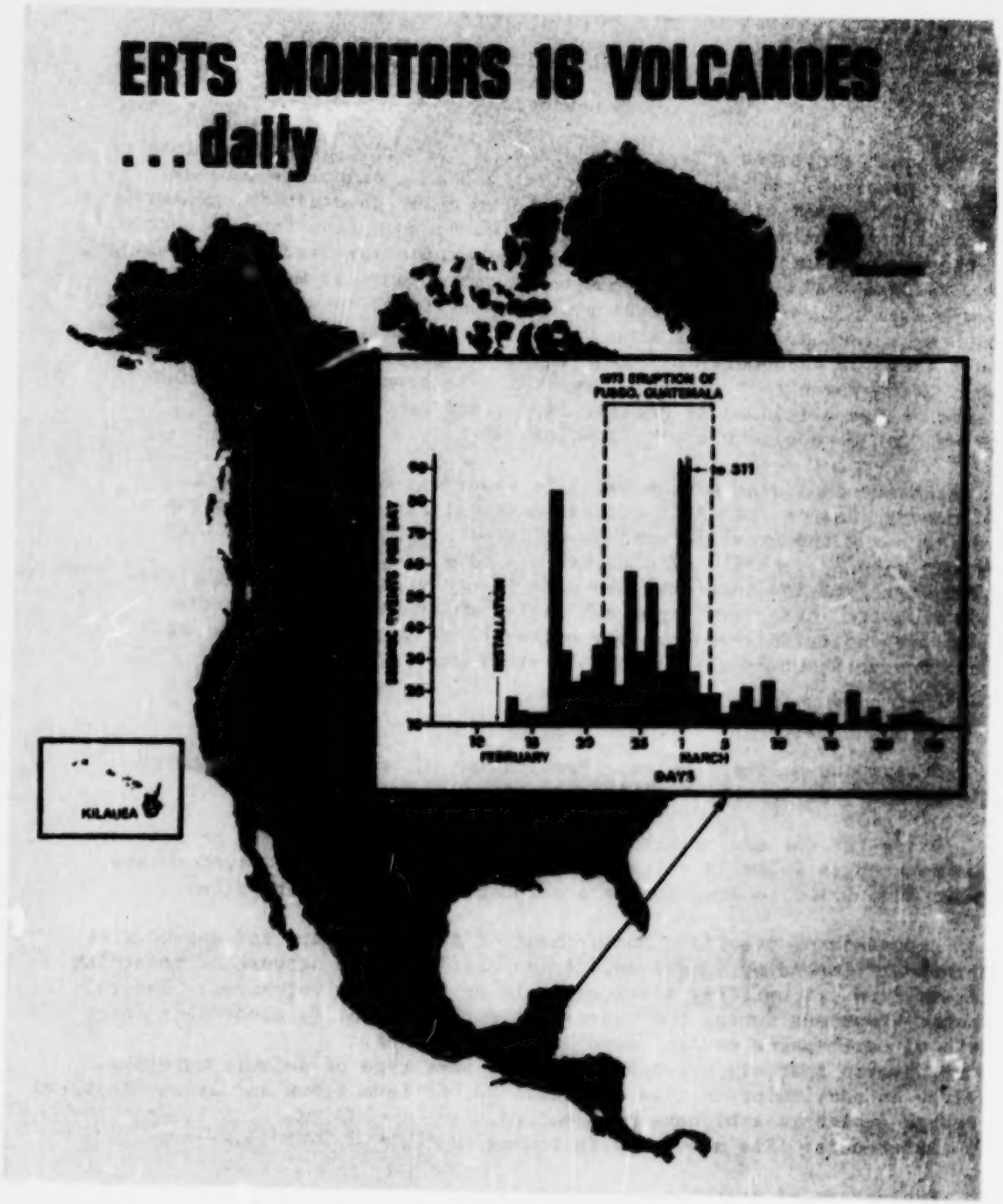

Figure 6. ERTS monitors 16 volcanoes daily with the Data Collection System. During February 1973, an increase in the number of seismic events preceded an eruption of Volcán Fuego in Guatemala. This data was relayed from the seismic event counter on the ground through the ERTS Data Collection System and thence to the Goddard Space Flight Center; but not evaluated until after the actual eruption.

Potential use of operational system:

Volcanic eruption warning system

Analysis of areas covered by new lava flows and vegetation (natural and croplands) blanketed by tephra.

Abstracts

A New Method for Monitoring Global Volcanic Activity

by

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U. S. Geological Survey
Menlo Park, California

Abstract

The ERTS Data Collection System has made it possible for the first time to collect significant data on the level of activity at widely separated volcanoes and relay these data nearly instantaneously to one central office for analysis by a small group of specialists. This new capability opens a new era in volcanology where the hundreds of normally quiescent but potentially dangerous volcanoes near populous regions around the world can be economically and reliably monitored daily to warn when any one volcano is becoming active again.

A prototype volcano surveillance system was established during the latter part of 1972 and early 1973 on 15 volcanoes in Alaska, Hawaii, Washington, California, Iceland, Guatemala, El Salvador, and Nicaragua. Nineteen seismic detectors that count four different sizes of earthquakes and six biaxial, borehole tiltmeters that measure ground tilt with a resolution of 1 microradian have been installed. Data from these instruments are relayed through the ERTS satellite and through a teletype link to the U.S. Geological Survey Office in Menlo Park for rapid analysis. Only seismic and tilt data are collected because these have been shown in the past to indicate most reliably the level of volcanic activity and these can be measured relatively easily with new instrumentation. Experience during this project demonstrates the feasibility of building inexpensive, low power, reliable instruments that can be installed in remote locations by most technicians and can be expected to run unattended for a few years.

Comparison of the data from these new earthquake counters with data from nearby standard seismometers show that the counters do normally indicate the level of seismic activity. During periods of high seismic background noise there may be a significant number of spurious counts but the existence and duration of such noisy periods are reliably indicated by other data sent by the earthquake counters. The only eruption to occur to date on any of the volcanoes under study was preceded by an abnormally large swarm of earthquakes several days before.

This work demonstrates the technical feasibility of a global volcano surveillance system but many details in the design of reliable instruments still need to be worked out. The primary effort in the future, however, needs to be the collection and analysis of data from these different volcanoes to establish clearly the scientific feasibility of this novel and potentially revolutionary approach to the surveillance of hazardous volcanoes.

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Establishment, Test, and Evaluation of a Prototype Volcano-Surveillance System

by

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United States Geological Survey
Menlo Park, California

Abstract

A volcano-surveillance system utilizing 23 multilevel earthquake counters and 6 biaxial borehole tiltmeters is being installed and tested on 15 volcanoes in 4 states and 4 foreign countries. The purpose of this system is to give early warning when apparently dormant volcanoes are becoming active. The data are relayed through the ERTS Data Collection System to Menlo Park for analysis. Installation was completed in 1972 on the volcanoes St. Augustine and Iliamna in Alaska; Kilauea in Hawaii; Baker, Rainier and St. Helens in Washington; Lassen in California; and at a site near Reykjavik, Iceland. Installation continues and should be completed in April 1973 on the volcanoes Santiaguito, Fuego, Agua, and Pacaya in Guatemala; Izalco in El Salvador; and San Cristobal, Telica and Cerro Negro in Nicaragua.

The event counters developed for this use count earthquakes of four different amplitudes. An earthquake is assumed if 10 peaks of a full-wave rectified seismic signal exceed a given threshold in 1.2 seconds and no peaks had exceeded the threshold in the previous 15 seconds. This latter criterion inhibits the counters if the ground noise is high for long periods of time. Inhibit times are counted on separate counters. All data are printed on a unique printer in the counter that provides a check on the reliability of the DCS. The average power consumption is only 2 milliwatts, and the counters are now operating reliably in a wide range of environments. Standard seismometers are being placed near most event counters in this initial program in order to verify that the counters are discriminating earthquakes as anticipated. Local earthquakes are being recorded at nearly all sites.

The biaxial tiltmeters are 2 inches in diameter and fit in a hole 5 feet deep. They are proving easy to install and are operating stably with a sensitivity of about one microradian.

Since this project was not funded until one month before the launch of ERTS-A, much of the first year of satellite life has been spent building and deploying equipment. The data available to date show that the instruments are working quite reliably and show how the system can be tuned to improve the data and reliability. The primary objective--evaluating the effectiveness of the system--must await more data.

Satellite Geological and Geophysical Remote Sensing of Iceland - Preliminary Results From Analysis of MSS Imagery

by

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Abstract

A binational, multidisciplinary research effort in Iceland is directed at an analysis of MSS imagery from ERTS-1 to study a variety of geologic, hydrologic, oceanographic, and agricultural phenomena. A preliminary evaluation of available MSS imagery of Iceland has yielded several significant results - some of which may have direct importance to the Icelandic economy. Initial findings can be summarized as follows: (1) recent lava flows can be delineated from older flows at Askja and Hekla; (2) MSS imagery from ERTS-1 and VHRR visible and infrared imagery from NOAA-2 recorded the volcanic eruption on Heimaey, Vestmann Islands; (3) coastline changes, particularly changes in the position of bars and beaches along the south coast (e.g., north and west of Ingólfshöfdi), are mappable; (4) areas covered with new and residual snow can be mapped, and the appearance of newly fallen snow on ERTS-1, MSS band 7 appears dark where it is melting; (5) sediment plumes from the discharge of glacial rivers along the south coast can be delineated; (6) the area encompassed by glacial ice (ice caps, valley and outlet glaciers, etc.) can be mapped, including the new position of a surging glacier, Eyjabakkajökull, and such related phenomena as nunataks and moraines;

(7) the plotting of changes in position of rivers, changes in size of lakes, and the occurrence of new lakes are feasible; (8) low sun-angle imagery, particularly of snow-covered terrain, markedly enhances the morphologic expression of constructional glacial and volcanic landforms, thus permitting the mapping of previously unrecognized structural features such as central or subglacial volcanoes; (9) the MSS color composites will permit the regional mapping of the gross distribution of vegetation in Iceland; and (10) at least at 1:250,000 map scale and smaller, ERTS-1 imagery provides a means of updating various types of maps of Iceland and will permit the compilation of special maps specifically aimed at those dynamic environmental phenomena which impact on the Icelandic economy.

Environmental Studies of Iceland With ERTS-1 Imagery

by

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Abstract

ERTS imagery has sufficient resolution to map, from MSS color composites, areas of altered ground caused by high-temperature geothermal activity at the Námafjall, Torfajökull, and Reykjanes geothermal areas. A small area of intense thermal emission on the east side of the Námafjall geothermal area could also be mapped because of the snowmelt pattern. The major axes of the fallout pattern of tephra from the May-July 1970 volcanic eruption from Hekla Volcano can be mapped where sufficient depth of deposition was sufficient to seriously affect the normal vegetation. Lava flows from the 1961 volcanic eruption at Askja; some of

the lava flows from the 1947-48 eruption, and all of the lava flows from the 1970 eruption at Hekla; and the areas covered by tephra and lava from the 1973 eruption on Heimaey could be delineated. Low sun angle imagery (<10°) of snow-covered terrain has been particularly valuable in mapping structural and volcanic features concealed beneath glacial ice in the active volcanic zones of Iceland. Such imagery has also shown the very marked differences in volcanic geomorphology from a regional standpoint within the active zones. Enlargements from standard (3d generation) negatives enabled planimetric revisions to be made to the 1:100,000-scale maps of the islands of Surtsey and Heimaey; a change in the former is the result of erosion, and a change in the latter is the result of new land created by the 1973 volcanic eruption. Changes in extent of snow cover with time can be monitored on successive images. The change in size of sediment plumes from the many glacial rivers which discharge into the sea along the south coast can be monitored and give a qualitative indication of seasonal changes in melting rates of glaciers. Changes in area of lakes, particularly glacier-margin lakes because of their powder-blue color, can be mapped most easily on MSS false-color composites. The increase in surface area of an ice-dammed lake was monitored until the occurrence of a jökulhlaup, after which the surface area of the lake was reduced considerably. ERTS imagery is especially amenable to showing the entire areal extent of Iceland's glaciers and icecaps at a point in time. New planimetric maps are under preparation at 1:500,000- and 1:250,000-scales which will accurately show the area of Iceland covered by glacial ice. Recently deglaciated terrain can be distinguished on MSS false-color composites because of the absence of vegetation when compared with older deglaciated terrain. ERTS imagery, acquired about 1 year apart, shows that the Eyjabakajökull glacier, an outlet glacier on the northeast part of Vatnajökull, has surged nearly 2 km. Some of the effects of subglacial geothermal and volcanic activity under Vatnajökull can be seen in the form of collapse features in the surface of the icecap, after the occurrence of two jökulhlaups. MSS false-color composites permit the mapping of at least five distinct vegetation types (forested areas, cultivated areas, grasslands, reclaimed areas, and lichen-covered bedrock) and barren areas (absence of color). The high latitude of Iceland permits considerable stereoscopic coverage on side-lapping ERTS imagery. Features with relief as little as 100 m can be discerned stereoscopically. This method of studying landforms, vegetation distribution, occurrence of snow cover, glaciers, and geologic structure stereoscopically generally permits a more precise analysis to be made of these phenomena.

Williams, R.S., Jr., Böðvarsson, Ágúst, Friðriksson, Sturla, Pálmason, Guðmundur, Rist, Sirgurjón, Sigtryggsson, Hlynur, Sæmundsson, Kristján, Thorarinsson, Sigurður, and Thorsteinsson, Ingvi, 1974, Environmental Studies of Iceland with ERTS-1 Imagery: in Proc. Ninth Symposium on Remote Sensing of Environment, Univ. of Mich., Ann Arbor, Mich., v. 1, p. 31-81.

Thermal Surveillance of Cascade Range Volcanoes Using ERTS-1 Multispectral Scanner, Aircraft Imaging Systems, and Ground-Based Data Communication Platforms

by

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Abstract

A combination of infrared images depicting areas of thermal emission and ground calibration points have proved to be particularly useful in plotting time-dependent changes in surface temperatures and radiance and in delimiting areas of predominantly convective heat flow to the earth's surface in the Cascade Range and on Surtsey Volcano, Iceland. In an integrated experiment group using ERTS-1 Multispectral Scanner (MSS) and aircraft infrared imaging systems in conjunction with multiple thermistor arrays, volcano surface temperatures are relayed daily to Washington via Data Communication Platform (DCP) transmitters and ERTS-1. Estimates of the magnitude of radiative and convective heat flow at several surface thermal manifestations in Lassen Volcanic National Park are providing data on the energy yield at the earth's surface during Lassen's current period of repose. Repetitive aircraft infrared imaging missions have recorded the outgoing radiative flux from the terrestrial surface, which has been essential in locating, delimiting and recording changes in surface thermal anomalies at Lassen, Mt. Ranier, Mt. St. Helens, Mt. Baker, Mt. Shasta and Mt. Hood. ERTS-1 MSS imagery has revealed curvilinear structures at Lassen, the full extent of which have not been previously mapped. Interestingly, the major surface thermal manifestations at Lassen are aligned along these structures, particularly in the Warner Valley. On Lassen Peak, and possibly at Mt. St. Helens, smaller thermal anomalies are controlled by the contact margines of silicic or intermediate extrusive plugs, and particularly at Lassen, may mark a line of structural weakness along Manzanita Creek Valley.

Drought

Description

Drought is a creeping disaster. The signs of drought are at first minimal, but over a period of months and years can culminate in serious water and food shortages, thereby causing great economic and personal damage. ERTS data have been used for drought analysis only in the Sahelian zone of West Africa, and the results are preliminary, but it is believed that valid extrapolation to additional experiments for operational use can be made. The basic advantage of ERTS data for drought analysis is the fact that the images are uniform and repetitive and thus can be readily compared for the detection of changes that may signal the signs of an impending drought. Such signs would be: (1) a decrease in surface water area, (2) a decrease in the area and vigor of vegetation, and (3), in some areas, the signs of desertification, such as movement of sand dunes and loss of agricultural productivity. In order to accomplish this "early warning system" an operational ERTS system would be required that would systematically acquire images over the land areas of the world; it would also require the creation of interdisciplinary photointerpretation teams that would systematically search the data for evidences of impending drought. This would, of course, be combined with knowledge from other public and private sources, including meteorological data from weather stations and the NOAA satellite. Data collection platforms in remote areas, with sensors which measure precipitation, air and dew point temperatures, soil moisture, etc., could also be employed. As an area became identified as a potential drought area, more attention would be focused on it, and more in-depth analyses would be made. At that time plans for relief efforts could be initiated to minimize the deleterious effects of impending drought.

If a drought is already underway, an *ex post facto* analysis can be made similar to that being done experimentally in the Sahelian zone of West Africa. This would involve the search for additional water supplies, analysis of the grazing and farming conditions of the land, identification of those areas where proper land management has warded off some of the greater affects of the drought, mapping the increasing desertification of the area, and verification of the rate of desertification.

Drought analysis of this type can be conducted with the ERTS data and existing supplementary meteorological data, and with the proper manpower, effort, and facilities, can be successful in helping to relieve the major effects of large-scale drought.

Summary

Definition of the problem: Warning of impending drought, planning of remedial measures, and monitoring of reclamation activities.

Basis for the use of ERTS data: Repeated synoptic view of large areas allows comparison of vegetation, water, and terrain changes with time to detect signs of incipient drought.

Experimental results: The only studies on droughts made to date are in the Sahelian zone of West Africa. They have shown that increasing desertification, decreases in vegetation, and changes in water conditions can be monitored over a large area. This research, however, has been done during the drought rather than before it occurred. Results also indicate that the difference between drought-affected areas and well-managed grazing areas is quite visible. Monitoring of farming and grazing areas for management decision is practical and undoubtedly will conserve agricultural land and improve productivity over future years.

References: See abstract following.

Evaluation of status of application: On the basis of work done to date, monitoring of drought-affected areas is feasible. Exploration for water supplies is feasible with ERTS data. Repetitive monitoring of areas that may be subject to drought to detect signs of incipient dryness is feasible but has not yet been done. It would require continued repetitive coverage of large areas of the world and photo analysis by interpretive teams. Supplementary meteorological data from weather stations and the NOAA weather satellite and, in the future, the use of data collection platforms in remote areas wou'd improve accuracy of imagery analysis.

Potential use of operational system:

1. Warning of impending drought
2. Exploration for water supplies
3. Monitoring of farming and grazing for management decision
4. Analysis of drought-affected areas
5. Development of water conservation practices for an area of imminent drought.

Abstract

Applications of Remote Sensing (ERTS) to Resource Management and Development in Sahelien Africa (Republic of Mali)

by

N. H. MacLeod
Department of Biology
The American University
Washington, D. C.

Abstract

The primary resource management problem in Sub-Saharan Africa (the Sahel) is increasing aridity or desertification. Space observations of sand streams, dune orientations, moisture and vegetation changes and other factors associated with desertification have been made. It is not yet known whether the process is caused by human activities or climatic changes or both.

A second major interest is grazing of cattle, sheep and goats which is associated with major movements of people and animals twice yearly to obtain forage -- from the savannah in fall and winter, and from huge areas of marsh (the Inland Delta) in spring and summer. These movements (transhumance) pass through more settled cultivators and into regions occupied by fishermen. The changes in available forage are being observed. The location of the cultivators is also being mapped from ERTS imagery -- for the first time. Field burning after rains is widely practiced and has been observed and the extent measured in ERTS imagery. In some areas of Mali, this measurement is an estimate of area to be planted to grain in the next season -- an unmeasured parameter heretofore.

Hydrological analysis is being carried on in the Niger and Bani River watersheds. The size, timing and areal extent of the annual flood is of particular interest. So far, good imagery of the maximum flood stage has been obtained and assessed.

Geologic information on fault zones, sand dune formations, scarps, tectonic basins and focal points of faulting (points from which fractures appear to radiate) are all visible and heretofore mapped inaccurately or not at all. The information on possible areas in which mineralization has occurred are being mapped and noted for Malien officials carrying on their own ERTS investigations.

Experimental results: The only studies on droughts made to date are in the Sahelian zone of West Africa. They have shown that increasing desertification, decreases in vegetation, and changes in water conditions can be monitored over a large area. This research, however, has been done during the drought rather than before it occurred. Results also indicate that the difference between drought-affected areas and well-managed grazing areas is quite visible. Monitoring of farming and grazing areas for management decision is practical and undoubtedly will conserve agricultural land and improve productivity over future years.

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Potential use of operational system:

1. Warning of impending drought
2. Exploration for water supplies
3. Monitoring of farming and grazing for management decision
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Grass and forest fires

Grass and forest fires may be started accidentally--for example by lightning--or deliberately for clearing native growth for agricultural purposes or to burn away crop stubble. Forest and grass burns are among the most easily recognized features on ERTS imagery because of their lower reflectivity, and they can be easily identified and mapped with a minimum of equipment and by interpreters with a minimum of training. Assessment of the areas burned, combined with previously made maps of vegetation type and cultural features, can be used for determining the percentage or area of a particular vegetation type burned and for identification of new agricultural areas. It has been suggested that identification of new agricultural areas created by burning is useful in the control of malaria because malaria control teams can then know exactly which areas should be sprayed for mosquito control. Because of the 18-day repeat time of ERTS imagery and the delay in receipt of images for analyses the images are not particularly useful for the assessment of fire conditions during burning or for specific fire control measures which must be done on an hourly or daily basis. In spite of this limitation, however, the assessment of burned areas is probably one of the easiest of ERTS imagery.

The Forestry Remote Sensing Laboratory of the University of California at Berkeley has analyzed fires in the State of California using ERTS imagery. They have concluded that the analysis of the area burned in a particular fire can be more accurately done by analysis of the ERTS image than by observers flying over the fire and drawing maps. The ERTS imagery can also be readily used to map the interior of large burned areas in detail and to monitor burned areas over periods of time to evaluate the re-growth of vegetation. Unburned areas within a large fire perimeter can easily be distinguished in the images. Figure 7 shows old and new burns in eastern South Africa which can be easily recognized and mapped.

Summary

Definition of the problem: Mapping the occurence and extent of grass and forest fires and regrowth after fires.

Basis for the use of ERTS data: Synoptic and repetitive imagery allows ready identification of burned areas, measurement of the burned areas, and assessment of rates of regrowth.

Experimental results: Both accidental and deliberate fires have been detected, mapped, and monitored in South Africa, Angola, Botswana, Rhodesia, and Zambia. Burned areas are readily recognizable on ERTS images and can be measured with reasonable accuracy. Maps of burned areas can be combined with previously made maps of vegetation type to assess the area and percentage of each type burned.

Fire hazard appraisal has been done in California to map areas of wild oats and blue gum trees which, in the dry season, are a great fire hazard.

References: See abstracts following.

Figure 7. -- Grass fires in the veld regions of eastern South Africa can be readily recognized and mapped on ERTS images. Old burns and new fires can be distinguished. The darkest areas are fires, in some areas partially bounded by previously cut firebreaks.

Scale 1:1,000,000. Image 1047-07187.

Evaluation of status of application: Completely feasible and readily accomplishable with a minimum of interpretive equipment. Interpreters can be quickly trained.

Potential use of operational system:

1. Assessment of areas burned by forest fires.

2. Assessment of veld and savanna burns for agricultural purposes or for wildlife habitat management.

3. Delineation of areas cleared for new agriculture in jungle regions.

Abstracts

Detection, Mapping and Estimation of Rate of Spread of Grass Fires From Southern African ERTS-1 Imagery

by

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Canadian Forestry Service
Ottawa, Ontario

Abstract

Sequential band-6 imagery of the Zambesi Basin of southern Africa recorded substantial changes in burn patterns resulting from late dry season grass fires. One example from northern Botswana, indicates that a fire consumed approximately 70 square miles of grassland over a 24-hour period. Another example from western Zambia indicates increased fire activity over a 19-day period. Other examples clearly define the area of widespread grass fires in Angola, Botswana, Rhodesia and Zambia.

From the fire patterns visible on the sequential portions of the imagery, and the time intervals involved, the rates of spread of the fires are estimated and compared with estimates derived from experimental burning plots in Zambia and Canada. It is concluded that sequential ERTS-1 imagery, of the quality studied, clearly provides the information needed to detect and map grass fires and to monitor their rates of spread in this region during the late dry season.

Preliminary Assessment of Veld Burning Patterns in Natal From ERTS-1 Imagery

J. L. Jarman (South Africa) included in "To assess the value of satellite imagery in resource evaluation on a national scale." Report on South African ERTS-1 investigations by Dr. O.G. Malan, Council for Scientific and Industrial Research, South Africa.

Conclusions:

This preliminary assessment has definitely proved the usefulness of ERTS imagery in investigating precisely the location, extent and time of burning in relation to vegetation type and management. The results have proved conclusively that monitoring of the burning pattern is a practical feasibility, provided suitable consecutive imagery is available.

As far as detecting burn areas on the imagery is concerned, small fires are more difficult to detect than large fires on the 1:1,000,000 black and white prints, but the Additive Colour Viewer removed this difficulty of differentiating between fires and water-bodies in band 7 and positively identified burn age whereas the prints were sometimes difficult to assess.

The 1:500,000 false colour photolithoprints are very suitable for burning inventory work.

It must be stressed that this is a preliminary assessment. Nevertheless, the data that have been collected for this investigation, with that obtained from a future operational satellite, will be invaluable for detailed investigations of burning practice which is a very important range management method.

Agricultural crop disasters

Description

Agricultural crop disasters include a variety of applications, because stress on crops may include lack of moisture, disease, insect infestations, and storms. It has long been the hope that stressed crops could be detected from satellite altitudes before the stresses became severe enough to damage the crops beyond redemption. This has not, however, been the case. Crops and forests that have been killed are identifiable and distinguishable from healthy crops, but pre-mortality stress is not readily evident. Nevertheless, the relative vigor of crops, their density, and areal extent can be readily assessed from ERTS imagery and, by spectral recognition techniques, many major crops can be identified.

The specific potential applications of interest are the winter-kill of grass in Iceland and the survey of locust breeding sites in Saudi Arabia, both of which are abstracted below.

Summary

Definition of the problem: Identifying areas of plant stress due to disease, insect infestation, pollution, or moisture deficiency.

Basis for the use of ERTS data: Spectral reflectance of plant changes as they are stressed. Measurement of the change indicates the presence of stress but not the specific cause, which must be checked on the ground.

Experimental results: Forest infestation and sulfur dioxide damage has been identified on ERTS images. To date, however, no specific cases of crop disease have been identified on ERTS images. Success has been achieved with aircraft monitoring of crop disease, particularly during the major experiment on corn blight in the midwestern United States during 1972. Further experiments with satellite data should be conducted before the application is either proven, shown to be limited to specific cases, or shown not to be feasible.

References: See abstracts following.

Evaluation of status of application: Proven for some specific cases of forest insect infestation and air pollution effects on forests but not ready for general application.

Potential use of operational system: Must await additional experimental results. If proven feasible, it could be highly beneficial in stopping spread of crop disease at early stages.

Abstracts

Application of ERTS-1 Imagery and Underflight Photography in the Detection and Monitoring of Forest Insect Infestations in the Sierra Nevada Mountains of California

by

Ralph C. Hall
Natural Resources Management Corporation
Berkeley, California

Abstract

Preliminary analysis of ERTS-1 imagery in a rugged mountain area in the Sierra Nevada Mountains of California indicates some promising possibilities of detecting two types of insect infestations as our primary objective and secondary detecting and mapping other features such as timber or untimbered areas; timber stand density; principal stream course, mountain meadows, lakes, massive rock outcrop and domes, riparian vegetation, grazing land and possible glaciers. We have used and found exceedingly useful, NASA underflight RC-10 imagery.

Impact of ERTS Images on Surveys of Forest Insect Infestations in Cook Inlet Basin, Alaska

by

James H. Anderson and John M. Miller
University of Alaska
Fairbanks, Alaska

F. Philip Weber
USDA Pacific SW Forestry Experiment Station
Berkeley, California

Enzo Becia
Alaska Department of Natural Resources
Anchorage, Alaska

Roy C. Beckwith
USFS, Institute of Northern Forestry
Fairbanks, Alaska

Abstract

Aerial surveys conducted during the past three summers by the U.S. Forest Service have identified a severe spruce beetle (Dendroctonus obesus (Mann.)) infestation to a 200,000 acre region west of Cook Inlet near the Tyonek Indian Reservation, and additional acreages identified on the Kenai Peninsula in the Kenai Moose Range and adjacent state and private lands. Estimates have been made of two billion board feet of white spruce killed or damaged by the spruce beetle; however, the large areal extent of the spreading infestation presents a difficult task for maintaining surveillance of the extent of the affected trees.

Techniques have been implemented using November 1972 ERTS-1 imagery of the Cook Inlet Basin to stratify damage to White spruce into three levels - healthy, newly killed, and old killed. The three step analysis was performed on the ERTS imagery. A color composite was created using color recombining of the bulk 70-mm transparencies, an optimum color composite was chosen for display and interpretation at 28 times enlargement on a Variscan scanner, and scene radiance differences were analyzed from microdensitometer scans.

As of now we have been able to map the pure spruce stands as being different from the mixed spruce - hardwood stands, and we have been able to map the extent of old killed spruce stands. Work is continuing with other ERTS scenes taken earlier in the growing season where snow was not a problem for the purpose of further stratification of damage in spruce.

SO_2 Damage to Forests Recorded by ERTS-1

by

Peter A. Murtha
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Canadian Forestry Service
Ottawa, Canada

Abstract

SO_2 fumes have been affecting the forests around Wawa, Ontario, since 1948. In one area the forest has been totally destroyed and only exposed ground remains. The affected forest has been under aerial surveillance for a number of years and was recently covered by high altitude, 1:160,000 aerial photography for damage assessment purposes. The area was selected as a Canadian Forestry Service ERTS test site and was imaged on four successive ERTS passes during the summer of 1973.

Image interpretation supported by electronic colour enhancement was used to delineate on ERTS imagery three damage zones (total kill, heavy kill and medium damage zones). The zones delineated on ERTS imagery are similar to the results of aerial sketch-mapping and air photointerpretation. Band 5 provided the greatest detail for assessing the damage to the forests, followed in successive order by bands 4, 6, and 7. Comparison with ERTS images obtained in the winter showed that even though the total kill could be separated from heavy kill damage zones, total kill could not be consistently separated from clear-cut logging, burned areas, frozen lakes and bogs.

ERTS Surveys a 500 KM^2 Locust Breeding Site in Saudi Arabia

by

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Abstract

From September 1972 to January 1973, ERTS-1 precisely located a 500 km^2 area on the Red Sea coastal plain of Saudi Arabia within which the Desert Locust (Schistocerca gregaria, Forsk.) bred successfully and produced many small swarms. Growth of vegetation shown by satellite imagery was confirmed from ground surveys and rainguage data. The experiment demonstrates the feasibility of detecting potential locust breeding sites by satellite, and shows that an operational satellite would be a powerful tool for routine survey of the 3×10^7 km^2 invasion area of the Desert Locust in Africa and Asia, as well as of other locust species in the arid and semi-arid tropics.

Icelandic grass winterkill

R. S. Williams, Jr.,[2/] U.S. Geological Survey, has reported that in northern and eastern Iceland the condition of rangelands for sheep pasture and forage is heavily dependent upon the amount of sea ice in the adjacent Atlantic during the late winter, spring, and summer months. If little sea ice is present or does not last for a long time during the winter, the severe temperature over the land is ameliorated sufficiently so that the grass will "winter over" and return to vigorous growth in the spring and thus be capable of supporting a large population of sheep. If, however, there are large amounts of sea ice and it lasts for a long time during the winter, spring, and into the summer, the grass will undergo winterkill or stunted growth, and will not be capable of supporting a large sheep population.

Monitoring the sea ice cover off the northern coast of Iceland may help in providing earlier knowledge of the amount of sea ice and its persistence, and thus allow an earlier decision on slaughtering or dispersal of sheep and on the carrying capacity of the range during the following summer. Continued monitoring of the sea-ice conditions, which would be a simple task from ERTS, could be done and the data provided to the Icelandic range managers. An experiment of this type has not yet been tried, because routine coverage by ERTS of Iceland and adjacent waters is not yet a reality. Such coverage must await construction of ERTS receiving stations in eastern Canada and northern Norway.

It would also be possible to use the NOAA meteorological satellites for more frequent ice monitoring. These satellites have about an 800 m resolution, which is coarser than ERTS, but they could provide twice daily coverage from Canada and Norway. During the dark part of the year, the thermal infrared sensors on the NOAA satellites could image the ice cover. This complementary use of the earth resources and meteorological satellites could provide very beneficial data.

Hail storm damage

Description

Hail storm damage to crops is widespread and frequent, although individual storms drop hail only on relatively restricted areas. The change in reflectance due to hail damage can be seen on the ERTS images. Only one case of hail damage has been analyzed and only with the black and white prints. The damaged area probably could also be readily delineated on a color composite as well.

2/ Williams, R. S., Jr., 1972, Satellite geological and geophysical remote sensing of Iceland (abs.): in Univ. Michigan Internat. Symposium on Remote Sensing of Environment, 8th, Ann Arbor, Mich., Proc., p. 1465-1466.

Figure 8 is a mosaic of MSS-5 ERTS-1 negative-print images illustrating an area damaged by wind, rain, and hail from a storm which occurred on July 1, 1973; the ERTS-1 overpass was a week later on July 8, 1973. The apparent damage area, from analysis of ERTS-1 imagery, is delineated with a solid line. A ground survey was also conducted, and the results are noted by a dashed line. Band 5 presented the greatest contrast for interpretation; however, reflectance contrasts were also apparent in bands 4 and 6. The damaged area was not apparent on band 7. The predominant land use in the area is agricultural, cultivation of small grains, and grazing lands. Note that the field boundaries and patterns discriminate between these two uses. The anomaly apparent in the hail-damaged area was increased reflectance relative to the surrounding landscape.

Summary

Definition of the problem: Mapping the extent of hail storm damage to crops and rangeland.

Basis for the use of ERTS data: Hail damage increases the reflectance of the damaged area relative to the surrounding landscape. The synoptic view of ERTS allows delineation of damage over large areas.

Experimental results: One case of hail storm damage in South Dakota was identified on ERTS image. It has a fair correlation with ground information.

Reference: None published.

Evaluation of status of application: Shown to be feasible in only one case. More data is required for comprehensive analysis. Technically, the application appears to be feasible but is not yet ready for operational application. Application may be hampered by the 18-day repeat cycle of ERTS.

Potential use of operational system: Evaluation of crop damage areas for yield forecasting and hail insurance purposes.

Glacier movement

Description

Periodic surges of glaciers can create dangerous floods by damming valleys from which the stored water may later break loose. The repetitive nature of ERTS imagery allows ready detection of changes in the glacial form and size that indicate the potential for surges (fig. 9) and a time-lapse view of the actual surges.

In addition, surveying a large glacial area for such changes can be done easily with ERTS images, whereas it would be extremely difficult and expensive by aircraft. The following text was prepared by R. M. Krimmel, Austin Post, and M. F. Meier, U.S. Geological Survey and is reproduced here as an example of the monitoring of glacial surges.

Figure 8. Hail damage area identified on an ERTS-1 image (negative print) is compared with the known area of hail damage. The heavy solid line indicates the area interpreted from the ERTS imagery; the dashed line indicates areas of heavy and light hail reported by residents of the area. The area analyzed from ERTS images corresponds fairly well to the area of heavy hail reported by residents. (Interpretation and imagery provided by Don Moore and Alvin Rusche, Remote Sensing Institute, South Dakota State University, Brookings; Delineation on ground provided by Merlin Williams, Department of Natural Resources Development, Division of Weather Modification, Pierre, South Dakota.) Scale 1:750,000. Images 1349-16545 and 1350-17003.

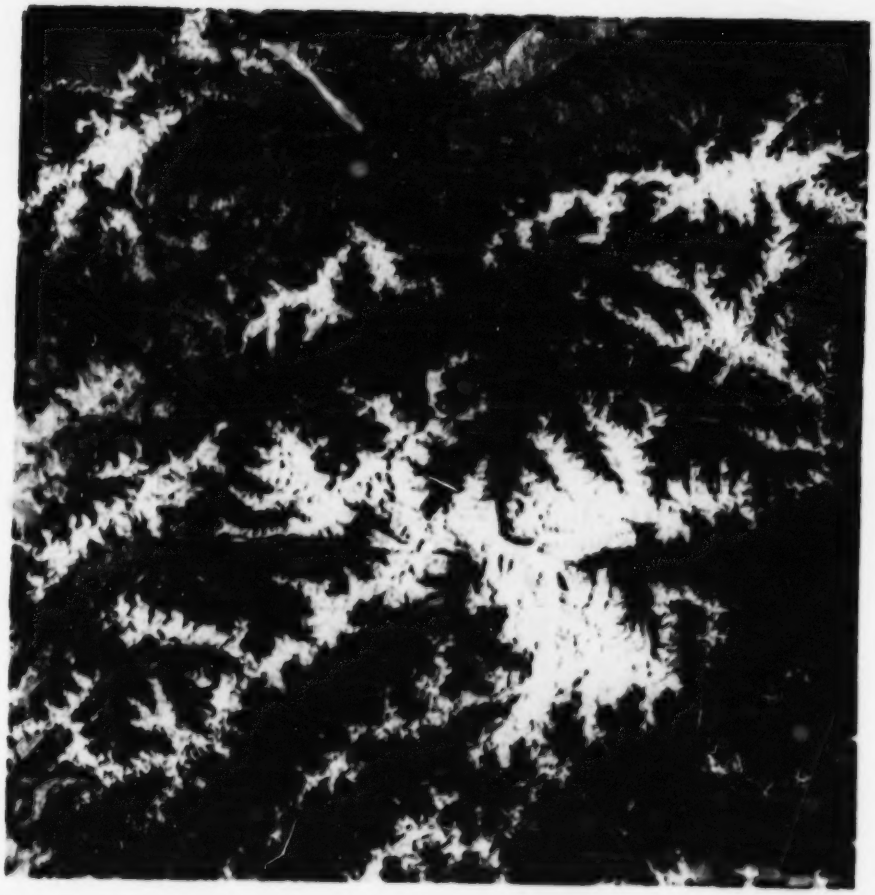

Figure 9. -- Surging glaciers in the Pamir Mountains, USSR, are shown in an ERTS image. Repetitive viewing of glacier areas allows checking of the areal extent of glaciers and identification of those that are in the initial stages of surging or that may surge.

Scale 1:1,330,000. Image 1354-05224.

Glacial floods can also be the result of subglacial volcanic and geothermal activity, as well as of failure of ice-dammed lakes. Both situations occur periodically in Iceland, where they are called jökulhlaups. Such floods may or may not be accompanied by surges of glaciers; glacier surges, however, have also been recorded on ERTS imagery of Iceland as discussed in the following summary by R. S. Williams, Jr., and others (1974).

Summary

Definition of the problem: Monitoring periodic surges of glaciers that can produce ice jams and floods.

Basis for the use of ERTS data: Repetitive imagery allows detection of changes in glacier shape and size and in morainal patterns which indicate rapid changes in movement. Synoptic view also allows scanning of large areas to detect potential surging glaciers.

Experimental results: Highly promising results indicate an excellent ability to spot surging glaciers and to measure movement and rate of movement in a time-lapse manner.

References: Basic references included in this report.

Evaluation of status of application: Experimental results have shown the feasibility of the application.

Potential use of operational system: Operational use would involve repeated systematic looks at major glaciers to find those that are surging or may surge and to warn of the possible effects of the surges.

Abstracts

Monitoring Surging Glaciers

by

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U. S. Geological Survey
Water Resources Division

ERTS Image 1354-05224

This image shows both surging and non-surging glaciers in the Pamir Mountains in Tadzhikistan in USSR. Most mountain glaciers move slowly (a few centimeters or tens of centimeters per day), and slowly adjust to changes in climate by gradual advances or retreats. Surging glaciers, on the other hand, periodically change from this slow regime to very rapid flow (metere per hour) causing rapid advances of the terminus amounting to one or more kilometers per month. Such rapid advances may cause lakes to be formed as tributary valleys are dammed by the advancing ice, and later these ice-dammed lakes may suddenly release causing a catastrophic flood.

In this ERTS image, the famous Medvezhii ("Bear") Glacier is shown just completing a catastrophic advance (surge) which caused widespread destruction. The glacier began to surge in April of 1973 and by early June had advanced nearly 3 km. The major threat of this surge was that the advancing ice dammed the Abdukagor River forming a lake that may have been larger than 20 million m^3 (700 million cubic feet) which on June 20, 1973, broke through its ice dam causing a flood in the populated Vanch River valley. Because the flood was expected to follow the damming of the river, dikes were built, bridges were dismantled, and other precautions were taken so no lives were lost, although highways and powerlines were damaged.

This image, obtained from the ERTS-1 satellite on July 12, 1972, from an altitude of 900 km (560 miles) over the Pamir Mountains shows a vast region of deep, arid valleys heading in large glaciers. As with such Western States as Washington, Montana, and Wyoming, summer ice melt from these glaciers supplies critically needed water to irrigate lands. Surges of the Medvezhii Glacier occur at intervals of 10-12 years. The Medvezhii Glacier is normally confined to the tributary valley of Khirsdara and advances out to the Abdukagor Valley only during surges. This glacier has been studied intensively by glaciologist Dr. Leonid D. Dolgushin and his colleagues of the Institute of Geography, Academy of Sciences of the USSR.

Glaciologists of the Geological Survey in Tacoma, Washington, have identified six other surging-type glaciers such as the Fortambek and Garmo on this remarkable ERTS image. These show the periodically

looped medial moraines which are unmistakable signs of past surges. One of these, the Bivachnyi Glacier, appears to be primed for a surge of about 2 km (1.2 miles) in the next year or so. Sixteen other glaciers appear to show surging features.

Also of interest in this image is the 77 km long Fedchenko Glacier, the longest in the continental USSR and one of the World's most studied glaciers. The parallel medial moraines on the Fedchenko indicate that it does not surge. Some non-surge related ice dammed lakes are visible at the margins of the Fedchenko Glacier; these lakes can also cause floods.

As surges and related floods occur abruptly with little or no prior warning, glaciologists in countries which have surging glaciers--such as Iceland, Canada, Argentina, Chile, USSR, and United States--are pooling information collected from intensive studies in order to locate and map hazardous situations, provide prior warning systems when surges and surge-related floods are expected, and, hopefully, to determine the causes of these remarkable movements. Because surging glaciers usually occur in relatively inaccessible terrain, satellites such as ERTS-1 will be used more and more for the required monitoring.

Meier, M. F., 1973, Evaluation of ERTS imagery for mapping and detection of changes of snowcover on land and on glaciers: Symposium on Significant Results Obtained from the Earth Resources Technology Satellite-1, v. 1, sec. A, New Carrollton, Maryland, NASA-SP-327, p. 863-875.

Dolgushin, L. D., and Osipova, G. B., 1972, Pul'satsii lednikov problema ikh prognoz irovaniia na primere lednika medveshch'ego (Zapadnyia Pamir): Akademii Nauk SSR, Izvestiia Seriia Geograficheskaia, no. 2, p. 89-98.

Water pollution monitoring

Description

Some types of water pollution are amenable to sensing by ERTS. They include suspended sediment distribution, chlorophyll concentration, algae blooms, and red tides. Abstracts of several papers describing such phenomena follow.

Dissolved pollutants, both organic and inorganic, are not amenable to satellite sensing. Future systems may be capable of their detection and measurement, but such systems are at present only in the laboratory stage.

Otterman and others (1974) have reported oil slicks on ERTS-1 images of the Gulf of Suez. The slicks were from ruptures of an underwater pipe near offshore oil production platforms.

Strong (1974) has mapped algae blooms in Lake Erie and Utah Lake from ERTS-1 imagery which were confirmed by observations from aircraft and boats.

Summary

Definition of the problem: Determining changes in water quality including sediment and chlorophyll concentration.

Basis for the use of ERTS data: Some pollutants change the reflectance of water sufficiently to be detected and in some cases quantified. Dissolved pollutants cannot readily be detected or measured by ERTS.

Experimental results: Sediment distribution in lakes, bays, esuaries, and ocean coastal areas can be detected and, in some cases, measured. Research is continuing on quantitative measurement.

Measurement of algal concentration has been done by ratioing ERTS radiance in several bands.

Some oil slicks have been detected.

Both red tide and some ocean disposal of waste can be detected on ERTS imagery.

References: Strong, A. E., 1974, Remote sensing of algae blooms by aircraft and satellites in Lake Erie and Utah Lake. Remote Sensing of Environment, v. 3, no. 2, p. 99-107.

Otterman, J., Ohring, G., and Ginsberg, A., 1974. Results of Israeli multidisciplinary data analysis of ERTS-1 imagery. Remote Sensing of Environment, v. 3, no. 2, p. 133-148.

Evaluation of status of application: ERTS imagery suitable for some types of pollution when the pollutants change the color of the water. So far it has not been proven suitable (nor was it designed) to detect and measure dissolved pollutants.

Potential use of operational system:

1. **Detection and measurement of suspended matter.**
2. **Detection of algal blooms, red tide, and some ocean dumping.**

Abstracts

Aircraft and Satellite Monitoring of Water Quality

by

James P. Scherz

Abstract

Aerial and Satellite Photography can be a very valuable tool for water quality investigations. Such aerial imagery correlates with the water quality parameter of turbidity, which in turn under specific circumstances, correlates to other water quality parameters such as suspended solids or apparent color. The advantage of aerial imagery is that it provides an overall view of turbidity possible by no other means. One striking example of this potential use is in Lake Superior where an $8,000,000 water intake was located in turbid, unpotable water. The turbidity and its location was clearly visible on aerial and ERTS imagery. Another example of its potential use is where apparent reflectance of various lakes in northern Minnesota as obtained from ERTS imagery correlates very well with the turbidity, solids, and the U.S. Forest Service classification of eutrophication for these lakes. For correct analysis of aerial imagery for water quality, one must understand light penetration into water and the corresponding bottom effects, as well as sky light reflection from the water surface. If these effects are understood and accounted for in a workable and practical manner, aerial and satellite imagery can indeed be a valuable tool for water quality investigations and should be used as such.

Monitoring Ocean Dumping with ERTS-1 Data

by

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Abstract

Large volumes of municipal and industrial wastes are disposed of by means of dumping at sea. Disposal of wastes by barge dumping frequently produces surface films and waste fields whose fate and effects are not adequately defined. Frequently very large areas of the marine environment are affected.

Described in this paper are the results of an analysis of ERTS-1 data for the New York Bight collected on 16 August 1972. Results are presented which show acid-iron wastes, sewage sludge, suspended solids, and major water mass boundary features in the study area. The potential of satellite remote sensing for monitoring large scale events such as ocean dumping is discussed.

Polluted and Turbid Water Masses in Osaka Bay and its Vicinity Revealed with ERTS-A Imageries

by

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Abstract

The heavy water pollution is one of the most serious problems in the Osaka Bay and its vicinity. However, the state of water pollution there has never monitored in the scale of whole Osaka Bay because the conventional point-to-point observations make it impossible to detect the periodical movement of water masses by the fairly strong tidal current.

ERTS-A took very valuable MSS imageries of Osaka Bay and its vicinity on October 24, 1972. In the MSS-4 and MSS-5 imageries a complex grey pattern of water masses can be seen. Though some of grey colored patterns seen in black and white prints of the MSS-4 and MSS-5 imageries are easily identified from their shapes as cloud covers or polluted water masses characterized by their color tone in longer wavelengths in the visible region, any correct distribution pattern of polluted or turbid water masses can be hardly detected separately from thin cloud covers in a quick look analysis.

In the present investigation, a simple photographic technique was applied using the fact that reflected sun light from cloud including smog and inclined water surfaces of wave have a certain component in the near infrared region, that is MSS 7, whereas the light scattered from fine materials suspended in the sea water has nearly no component in the channel of MSS 7 but has only the green and yellow component sensible in MSS 4 and MSS 5 channels. That is, combined prints were made from a positive imagery of MSS-4 or 5 together with a negative imagery of MSS-7 using a photographic enlarger. In the combined prints areas of clouds and smogs are shown as white or lighter grey, whereas polluted or turbid water masses are clearly represented with black or darker grey tone.

ERTS-1 Observes Algal Blooms in Lake Erie and Utah Lake

by

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Abstract

During late summer when the surface waters of Lake Erie reach their maximum temperature an algal bloom is likely to develop. Such phenomena have been noticed on other shallow lakes using ERTS-1 and characterize eutrophic conditions. The concentration of the algae into long streamers provides additional information on surface circulations. To augment the ERTS-1 MSS data of Lake Erie an aircraft was flown to provide correlative thermal-IR and additional multiband photographs. The algal bloom is highly absorptive in the visible wavelengths but reverses contrast with the surrounding water in the near-IR bands. The absorption of shortwave energy heats the dark brown algal mass, providing a hot surface target for the thermal-IR scanner.

Red Tide in Ise Bay

by

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Abstract

From 5th to 26th of October 1972, the northwestern part of Ise Bay was seriously suffered by the dense red tide. The estimated boundary of red tide due to ship's observations were shown in Fig. 1. The area spread to eastward along the western coast of Ise Bay. However, ship's observations are sometimes not so correct because most of observation ships in Ise Bay are very small fishing boats not equipped with efficient navigation instruments to get their position exactly.

So the author tried to find out the correct boundary of red tide as an environmental pattern using several imageries produced from ERTS-1 data. The green band with 0.50-0.60 wavelength is expected to detect the underwater circumstance where the transparency is in good condition. Where the transparency is not enough, the underwater circumstance can not be detected but only the surface circumstance.

The transparency distribution of Ise Bay as shown in Fig. 2 shows that the area along the western coast near Yokkaichi was in no good condition, while the green band imagery as shown in Fig. 3 shows the two black patterns as pointed out with arrows. They are extended to the northeastern direction and the southeastern direction respectively like as belt, which are supposed the area of red tide on October 5, 1972. If additional ERTS-A imagery dated Feb. 8, 1973, is available, the red tide spread over whole area of Ise Bay could be detected as somewhat different patterns on the basis of the groundtruth surveys.

ERTS OPERATIONAL POTENTIAL IN DISASTER SITUATIONS

Operational ERTS-type satellites could be of significant aid in the assessment of disasters on a worldwide basis. Several events must come to pass, however, before this goal can be achieved. They are as follows:

1. The commitment by the U.S. Government to the creation and long-term maintenance of an operational ERTS-type satellite system and associated data processing and distribution system.

2. Commitments by other countries, as they desire, to the construction and operation of their own or regional ground receiving stations, data processing, and image distribution facilities.

3. Training of image interpreters who can be ready to work with ERTS images on short notice in disaster situations.

4. Creation of a "quick-look" capability for rapid analysis and screening of ERTS images as they are received.

5. Formal agreements with the operational satellite management agency for high-priority coverage of disaster areas upon request, with reimbursement of costs for images and services.

6. Means for quick delivery of images to the proper authorities in affected countries.

Images from the present experimental satellites ERTS-1 (LANDSAT-1) and ERTS-2 (LANDSAT-2) can be made available through arrangements between AID and NASA, in the case of quick response to an immediate disaster; and between AID and USGS, for long-term disaster assessment, warning, or planning studies.

In South and Central America, the Inter-American Geodetic Survey (IAGS) is acting as a lead agency in applications of ERTS data and coordinates most experiments and data use throughout the region. ERTS investigators receive data from IAGS and, in addition, use the IAGS radio network to warn of disasters. This system could be utilized on an operational basis to speed data requests in disaster situations.

Requirements for disaster coverage

In order to provide satellite data on major disasters certain requirements must be met. Although some of these may seem quite obvious, it is nevertheless important that they be considered. These requirements are listed below and discussed in more detail later. In addition, a data bank of previously collected (pre-disaster) ERTS-1 images should be set up and made available to interpreters for quick comparison with images collected during or after a disaster.

1. At the time of the disaster, there must be a satellite or satellites in orbit capable of providing the relevant data.

2. Ground receiving stations must be in working order and capable of receiving the data.

3. The operators of the satellite, ground receiving stations, and data-processing systems must be willing and able to respond to an immediate call for disaster coverage and to forward the required images.

4. The images must be processed and made available to disaster interpreters on a priority basis in the shortest possible time.

5. Teams of interpreters must be capable, immediately available, properly staffed, and equipped to provide the needed interpretations.

6. The satellite images and interpretations must be provided in a usable form for management decision to the persons who are making decisions on disaster relief.

7. The data and interpretations must be delivered to the affected countries in time for decision and action.

Each of these requirements is in itself important, and if any one of them is weak in its scope, achievement, or capability, the end product will not be useful, either because of its basic inadequacy or because of its lack of timeliness. Figure 10 shows a schedule of events for disaster monitoring. As an example of this sequence we can consider the Managua earthquake of December 23, 1972. An immediate call to NASA elicited a prompt response, and on the next available pass of ERTS-1 over Managua, which luckily was on December 24, 1972, images were taken. They were received immediately, processed, and placed in the hands of interpreters on December 25, 1972, and within a week were in the hands of Nicaraguan authorities. In addition, NASA aircraft photographed the area of destruction in Managua on the 27th and 29th of December 1972. These aerial photographs were used for an assessment of damage to individual structures and transportation routes. This entire sequence of events was hurriedly planned; missions were scheduled and flown, and interpreters were assigned because of the opportunity to document the effects of a major earthquake event with data from ERTS and aircraft. Although the entire operation had a large degree of success, it would have been far better with sufficient preplanning. It is also worthy of note that through a great deal of luck, the next available pass of ERTS after the earthquake was on the following day. That time span could have been as much as 17 days under ideal weather conditions or several months under adverse weather conditions.

Operational system characteristics

A future ERTS operational system is now in the initial planning stages, although it is not yet an approved program. The characteristics of an operational system, based on the present ERTS configuration and experimental results, is expected to be similar in design and data products to the present experimental system. However, there will undoubtedly be increased reliability of system components and increased lifetime of the satellite, sensors, and tape recorders.

Sudden Disaster Monitoring

Schedule of Events for an ERTS-Type Satellite

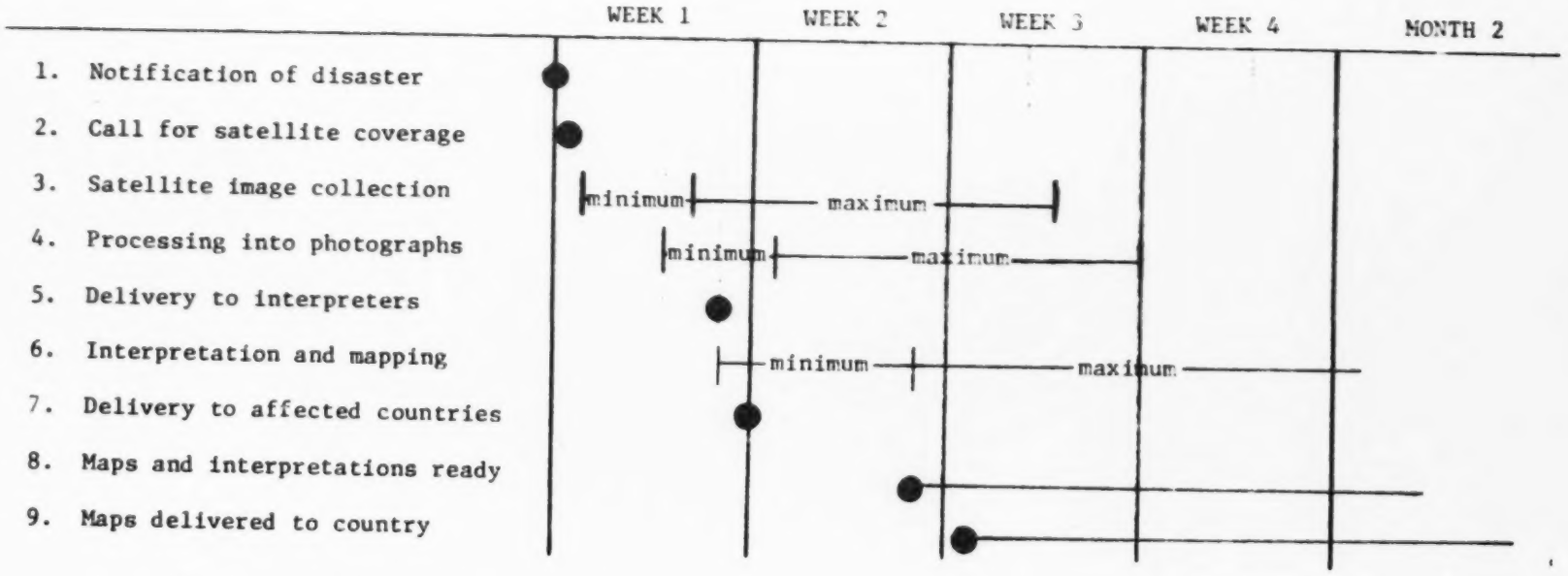

Figure 10. Disaster coverage, delivery, and interpretation schedules can be as short as 1 week if coverage can be obtained during or immediately after a disaster. The timing for delivery of interpretive results varies according to the availability of qualified interpreters, the complexity of the disaster, and the complexity of the interpretive techniques required. In any case, however, some results should be available within a maximum time of 1 month after the disaster.

An operational spacecraft and sensors would continue to provide digital scanner data that could be processed by digital computer and could also be converted to photographic form for photointerpretation. Ground receiving stations for the satellite data are presently located on the east and west coasts of the conterminous United States, in Alaska, Canada, Brazil, and Italy.

Plans are being made for stations in Iran, Norway, and Zaire. Such stations, and others that may eventually be set up in other nations, would provide data in and near countries where disasters might occur and to which data could be delivered quickly for disaster analysis. Other stations such as Santiago, Chile, and Ancon, Peru, are being considered for DCS reception only.

The basic components that must be designed into an operational system to make it most usable for disaster monitoring and which are different than those of the ERTS experimental system are:

1. A "quick look" capability at all reception stations.

2. Greatly shortened data processing time.

3. Dissemination of data within 48 hours after its acquisition.

4. Increased reliability of satellite and sensor components and longer lifetime.

These characteristics plus contingency plans for disaster use can make the operational use of satellite data for disaster warning and assessment a practical and usable tool.

Rapid data distribution to users

Immediate and timely use of ERTS data in disaster situations requires delivery of images to interpretive teams as soon as possible after the images are taken and received at ground receiving stations. Several actions must be taken to ensure such rapid delivery:

1. Agreement must be reached with the data reception agency to process and print disaster data on a priority basis (interrupting the normal processing flow), when a call is made by AID for disaster coverage.

2. Processing plans for various contingencies must be made in advance, so that requests for specific products can be readily satisfied. For example, one type of request could be for immediate delivery of 1:1,000,000-scale transparencies of all bands, to be followed, within 2 days, by 1:500,000-scale color composites. Such plans would depend on the nature of the disaster and the interpretive method to be employed.

3. Plans for rapid delivery of data from the data processing agency to AID (or the specified interpretive team) must be ready. This might involve couriers who hand-carry the data on the next available flight or by air express or air mail.

4. Delivery to interpretive teams must also be arranged. This will depend on the location of the team members.

5. Arrangements for rapid delivery of data to affected countries must be made. A possible method is by diplomatic pouch.

APPLICATIONS IN DEVELOPING COUNTRIES

The use of ERTS data for disaster warning and assessment in developing countries is quite feasible and may be done, at the country's choice, by one, or combinations, of three methods:

1. Nationals of the country involved may receive the data from U.S. or regional ground receiving stations and perform their own disaster interpretations.

2. The affected country may rely wholly on U. S. agencies and scientific personnel for interpretation, mapping, and analysis.

3. The affected countries may contract with qualified commercial organizations (either U.S. or foreign) for analysis of ERTS images.

Selection of one of these choices is up to the individual countries. It is recommended, however, that AID personnel in affected countries be apprised of the means of disaster assessment with ERTS images and be in a position to facilitate the reception, distribution, and analysis of ERTS images within the countries where they have responsibilities.